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Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Mineral Mining and Processing Point Source Category

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Development Document for Effluent Limitations Guidelines and Standards

Final

Mineral Mining and Processing Industry

Point Source Category

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This document presents the findings of an extensive study of the mineral mining and processing industry for the purpose of developing effluent limitations guidelines for existing point sources and standards of performance and pretreatment standards for new sources, to implement Sections 301, 304, 306 and 307 of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1551, 1314, and 1316, 86 Stat. 816 et. seq.) (the 'Act'). Effluent limitations set forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available (BPCTCA) and the degree of effluent reduction attainable through the application of the best available technology economically achievable (BATEA) which must be achieved by existing point sources by July 1, 1977 and July 1, 1983, respectively. The standards of performance (NSPS) and pretreatment standards for new sources set forth the degree of effluent reduction which are achievable through the application of the best available demonstrated control technology, processes, operati, ...

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DEVELOPMENT DOCUMENT
for
EFFLUENT LIMITATIONS GUIDELINES
and
NEW SOURCE PERFORMANCE STANDARDS

for the

MINERAL MINING AND PROCESSING
POINT SOURCE CATEGORY

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ABSTRACT

This document presents the findings of an extensive study of the mineral mining and processing industry for the purpose of developing effluent limitations guidelines for existing point sources and standards of performance and pretreatment standards for new sources, to implement Sections 301, 304, 306 and 307 of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1551, 1314, and 1316, 86 Stat. 816 et. seq.) (the "Act").

Effluent limitations set forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available (BPCTCA) and the degree of effluent reduction attainable through the application of the best available technology economically achievable (BATEA) which must be achieved by existing point sources by July 1, 1977 and July 1, 1983, respectively. The standards of performance (NSPS) and pretreatment standards for new sources set forth the degree of effluent reduction which are achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives.

Supporting data and rationale for development of the effluent limitations guidelines and standards of performance are contained in this report.

CONTENTS

Section — Page

Abstract

I Summary

II Recommendations

III Introduction

IV Industry Categorization

V Water Use and Waste Characterization

VI Selection of Pollutant Parameters

VII Control and Treatment Technology

VIII Cost, Energy and Non-Water Quality Aspects

IX Effluent Reduction Attainable Through the Application of the Best Practicable Control Technology Currently Available

X Effluent Reduction Attainable Through the Application of the Best Available Technology Economically Achievable

XI New Source Performance Standards and Pretreatment Standards

XII Acknowledgements

XIII References

XIV Glossary

Preceding page blank

FIGURES

Figure Page

1 Dimension Stone Distribution

2 Crushed Stone Distribution

3 Sand and Gravel Distribution

4 Industrial Sand Deposits

5 Gypsum and Asbestos Operations

6 Lightweight Aggregates, Mica and Sericite Operations

7 Barite Processing Plants

8 Fluorspar Processing Plants

9 Potash Deposits

10 Borate Operations

11 Lithium, Calcium and Magnesium

12 Rock Salt Mines and Wells

13 Phosphate Mining and Processing Locations

14 Sulfur Depösts

15 Supply-Demand Relationships for Clays

16 Dimension Stone Mining and Processing

17 Crushed Stone Mining and Processing

18 Sand and Gravel Mining and Processing

19 Industrial Sand Mining and Processing

20 Gypsum Mining and Processing

21 Bituminous Limestone Mining and Processing, Oil Impregnated Diatomite Mining and Processing, and Gilsonite Mining and Processing

22 Asbestos Mining and Processing

Preceding page blank

23 Wollastonite Mining and Processing

24 Perlite Mining and Processing, Pumice Mining and Processing, and Vermiculite Mining and Processing

25 Mica Mining and Processing

26 Barite Mining and Processing

27 Fluorspar Mining and Processing

28 Minerals Recovery from Searles Lake,
Minerals Recovery at Great Salt Lake, and
Lithium Salt Recovery Natural Brine,
Silver Peak Operations

29 Borate Mining and Processing

30 Potassium Chloride Mining and Processing From Sylvinite Ore, Langbeinite Mining and Processing, and Potash Recovery by Solution Mining of Sylvinite

31 Trona Ore Processing by the Monohydrate Process and Trona Ore Processing by the Sesquicarbonate Process

32 Sodium Sulfate from Brine Wells

33 Rock Salt Mining and Processing

34 Phosphate Mining and Processing

35 Sulfur Mining and Processing (Frasch Process)

36 Mineral Pigments Mining and Processing

37 Spodumene Mining and Processing (Flotation Process)

38 Bentonite Mining and Processing

39 Fire Clay Mining and Processing

40 Fuller's Earth Mining and Processing

41 Kaolin Mining and Processing

42 Ball Mining and Processing

43 Feldspar Mining and Processing

44 Kyanite Mining and Processing

45 Magnesite Mining and Processing

46 Shale Mining and Processing

47 Aplite Mining and Processing

48 Talc, Steatite, Soapstone and Pyrophyllite Mining and Processing

49 Talc Mining and Processing

50 Pyrophyllite Mining and Processing (Heavy Media Separation)

51 Garnet Mining and Processing

52 Tripoli Mining and Processing

53 Diatomite Mining and Processing

54 Graphite Mining and Processing

55 Jade Mining and Processing

56 Novaculite Mining and Processing

57 Normal Distribution of Log TSS for a Phosphate Slime Pond Discharge

58 Bleedwater Treating Plant

TABLES

Table Page

1 Recommended Limits and Standards

2 Data Base

3 Production and Employment

4 Dimension Stone by Use and Kind of Stone

5 Size Distribution of Crushed Stone Plants

6 Uses of Crushed Stone

7 Size Distribution of Sand and Gravel Plants

8 Uses of Sand and Gravel

9 Uses of Industrial Sand

10 Industry Categorization

11 Dimension Stone Water Use

12 Settling Pond Performance Stone, Sand and Gravel Operations

13 Fluorspar Mine Dewatering Data

14 Sulfur Facilities, Comparison of Discharges

15 Dimension Stone Treatment Costs

16 Crushed Stone Treatment Costs

17 Construction Sand and Gravel (Wet Process) Treatment Costs

18 Industrial Sand (Wet Process) Treatment Costs

19 Industrial Sand (Acid and Alkaline Process) Treatment Costs

20 Industrial Sand (HF Flotation) Treatment Costs

21 Gilsonite Treatment Costs

22 Vermiculite Treatment Costs

Preceding page blank

23 Mica Treatment Costs
24 Barite (Wet Process) Treatment Costs
25 Barite (Flotation Process) Treatment Costs
26 Fluorspar (HMS Process) Treatment Costs
27 Fluorspar (Flotation Process) Treatment Costs
28 Borates Treatment Costs
29 Potash (Carlsbad Operations) Treatment Costs
30 Potash (Moab Operations) Treatment Costs
31 Trona Treatment Costs
32 Rock Salt Treatment Costs
33 Phosphate Rock (Eastern) Treatment Costs
34 Phosphate Rock (Western) Treatment Costs
35 Sulfur (Anhydrite) Treatment Costs
36 Sulfur (On-Shore Salt Dome) Treatment Costs
37 Sulfur (Off-Shore Salt Dome) Treatment Costs
38 Mineral Pigments Treatment Costs
39 Lithium Minerals Treatment Costs
40 Attapulgite Treatment Costs
41 Montmorillonite Treatment Costs
42 Montmorillonite Mine Water Treatment Costs
43 Wet Process Kaolin Treatment Costs
44 Ball Clay Treatment Costs
45 Wet Process Feldspar Treatment Costs
46 Kyanite Treatment Costs
47 Wet Process Talc Minerals Treatment Costs
48 Conversion Table

SECTION I

SUMMARY

This study included the non-metallic minerals given in the following list with the corresponding Standard Industrial Classification (SIC) code.

- Dimension Stone (1411)
- Crushed Stone (1422, 1423, 1429)
- Construction Sand and Gravel (1442)
- Industrial Sand (1446)
- Gypsum (1492)
- Asphaltic Minerals (1499)
    - a. Bituminous Limestone
    - b. Oil Impregnated Diatomite
    - c. Gilsonite
- Asbestos and Wollastonite (1499)
- Lightweight Aggregate Minerals (1499)
    - a. Perlite
    - b. Pumice
    - c. Vermiculite
- Mica and Sericite (1499)
- Barite (1472)
- Fluorspar (1473)
- Salines from Brine Lakes (1474)
- Borates (1474)
- Potash (1474)
- Trona Ore (1474)
- Phosphate Rock (1475)
- Rock Salt (1476)
- Sulfur (Frasch) (1477)
- Mineral Pigments (1479)
- Lithium Minerals (1479)
- Sodium Sulfate (1474)
- Bentonite (1452)
- Fire Clay (1453)
- Fuller's Earth (1454)
    - A. Attapulgite
    - B. Montmorillonite
- Kaolin and Ball Clay (1455)
- Feldspar (1459)
- Kyanite (1459)
- Magnesite (Naturally Occurring) (1459)
- Shale and other Clay Minerals (1459)
    - A. Shale
    - B. Aplite
- Talc, Soapstone, Pyrophyllite, and Steatite (1496)
- Natural Abrasives (1499)

- A. Garnet
- B. Tripoli

Diatomite (1499)

Graphite (1499)

Miscellaneous Non Metallic Minerals (1499)

- A. Jade
- B. Novaculite

SECTION II

RECOMMENDATIONS

A summary of the effluent limitations is set forth in Table 1.

This development document is issued in support of final effluent limitations guidelines, based on the best practicable technology currently available (BPT), for existing sources in the following subcategories of the mineral mining point source category:

Crushed Stone
Sand and Gravel
Industrial Sand
Phosphate Rock

This development document also incorporates the documentation which was issued earlier in support of interim final regulations which were published on October 16, 1975 for the following additional subcategories:

Gypsum
Asphaltic Minerals
Asbestos and Wollastonite
Barite
Fluorspar
Salines
Borax
Potash
Graphite
Sodium Sulfate
Frasch Sulfur
Bentonite
Magnesite
Diatomite
Jade
Novaculite
Tripoli

Furthermore, this development document incorporates the documentation which was developed earlier in support of proposed regulations issued on October 16, 1975 and June 10, 1976 for the following subcategories:

Crushed Stone
Sand and Gravel
Industrial Sand
Phosphate Rock
Fluorspar
Salines
Borax
Gypsum
Asphalt
Asbestos
Barite
Magnesite
Diatomite
Jade
Potash
Sodium Sulfate
Frasch Sulfur
Bentonite
Novaculite
Tripoli
Graphite

Finally, this development document sets forth in draft form the basis for developing at a later date limitations for the following subcategories:

Dimension Stone
Lightweight Aggregate Minerals
Mica and Sericite
Salines from Brine Lakes
Trona
Talc, soapstone, pyrophyllite and steatite
Garnet

Rock Salt
Mineral pigments
Lithium Minerals
Fine Clay
Fuller's Earth

Shale and other clay

TABLE 1
Recommended Limits and Standards

The following apply to process waste water except where noted.

Subcategory	BPCTCA max. avg. of 30 consecutive days	BPCTCA max. for any one day	BATEA and NSPS max. avg. of 30 consecutive days	BATEA and NSPS max. for any one day
Dimension stone	No discharge		No discharge	
Mine dewatering		TSS 30 mg/l		TSS 30 mg/l
Crushed stone	TSS 25 mg/l	TSS 45 mg/l	TSS 25 mg/l	TSS 45 mg/l
Mine dewatering	TSS 25 mg/l	TSS 45 mg/l	TSS 25 mg/l	TSS 45 mg/l
Construction Sand and Gravel	TSS 25 mg/l	TSS 45 mg/l	TSS 25 mg/l	TSS 45 mg/l
Mine dewatering	TSS 25 mg/l	TSS 45 mg/l	TSS 25 mg/l	TSS 45 mg/l
Industrial Sand				
Dry processing,	No discharge		No discharge	
Wet processing, &				
Non HF flotation	TSS 25 mg/l	TSS 45 mg/l	TSS 25 mg/l	TSS 45 mg/l
HF flotation	TSS 0.023 kg/kkg F 0.003 kg/kkg	TSS 0.046 kg/kkg F 0.006 kg/kkg	No discharge	
Acid Leaching	No recommendation		No recommendation	
Mine dewatering	TSS 25 mg/l	TSS 45 mg/l	TSS 25 mg/l	TSS 45 mg/l
Gypsum				
Dry & Heavy Media Separation	No discharge		No discharge	
Wet Scrubbers	No discharge		No discharge	
Mine dewatering		TSS 30 mg/l		TSS 30 mg/l
Bituminous limestone, Oil-impregnated diatomite, & Gilsonite	No discharge		No discharge	
Asbestos Wollostonite	No discharge		No discharge	
Mine dewatering		TSS 30 mg/l		TSS 30 mg/l
Perlite, Pumice, Vermiculite & Expanded lightweight aggregates	No discharge		No discharge	
Mine dewatering		TSS 30 mg/l		TSS 30 mg/l
Mica & Sericite				
Dry processing, Wet processing & Wet processing and general clay recovery	No discharge		No discharge	
Wet processing and Ceramic grade clay recovery	TSS 1.5 kg/kkg	TSS 3.0 kg/kkg	TSS 1.5 kg/kkg	TSS 3.0 kg/kkg
Mine dewatering		TSS 30 mg/l		TSS 30 mg/l
Barite				
Dry	No discharge		No discharge	
Wet & Flotation	No discharge		No discharge	
Tailings pond storm overflow		TSS 30 mg/l		TSS 30 mg/l
Mine dewatering (acid)	TSS 35 mg/l Total Fe 3.5 mg/l	TSS 70 mg/l Total Fe 7.0 mg/l	TSS 35 mg/l Total Fe 3.5 mg/l	TSS 70 mg/l Total Fe 7.0 mg/l
Mine dewatering (non acid)		TSS 35 mg/l		TSS 35 mg/l

Fluorspar				
Heavy Media Separation & Drying and Pelletizing	No discharge		No discharge	
Flotation	TSS 0.6 kg/kkg F 0.2 kg/kkg	TSS 1.2 kg/kkg F 0.4 kg/kkg	TSS 0.6 kg/kkg F 0.1 kg/kkg	TSS 1.2 kg/kkg F 0.2 kg/kkg
Mine Drainage		TSS 30 mg/l		TSS 30 mg/l
Salines from Brine Lakes**	No discharge		No discharge	
Borax	No discharge		No discharge	
Potash	No discharge		No discharge	
Trona (process waste water & mine dewatering)	No discharge		No discharge	
Sodium Sulfate	No discharge		No discharge	
Rock Salt (process waste water & mine dewatering)	TSS 0.02 kg/kkg	TSS 0.04 kg/kkg	TSS 0.002 kg/kkg	TSS 0.004 kg/kkg
Salt pile runoff			No discharge	
Phosphate Rock and mine dewatering	TSS 30 mg/l	TSS 60 mg/l	TSS 30 mg/l	TSS 60 mg/l
Sulfur (Frasch)				
Anhydrite	No discharge			
Salt domes(land and marsh operations well bleed water)	TSS 50 mg/l*	TSS 100 mg/l*	TSS 30 mg/l*	TSS 60 mg/l*
Land available	S 1 mg/l	S 2 mg/l	S 1 mg/l	S 2 mg/l
Limited Land available	S 5 mg/l	S 10 mg/l	S 2 mg/l	S 4 mg/l
Well seal water			TSS 30 mg/l* S 1 mg/l	TSS 60 mg/l* S 2 mg/l
Mineral Pigments	No discharge		No discharge	
Mine dewatering		TSS 30 mg/l		TSS 30 mg/l
Lithium***	No discharge		No discharge	
Tailings dam seepage & storm overflow		TSS 50 mg/l		TSS 50 mg/l
Mine dewatering		TSS 35 mg/l		TSS 35 mg/l
Bentonite	No discharge		No discharge	
Mine dewatering		TSS 35 mg/l		TSS 35 mg/l
Fire clay	No discharge		No discharge	
Non-Acid mine dewatering		TSS 35 mg/l		TSS 35 mg/l
Acid Mine dewatering	TSS 35 mg/l Total Fe 3.5 mg/l	TSS 70 mg/l Total Fe 7 mg/l	TSS 35 mg/l Total Fe 3.5 mg/l	TSS 70 mg/l Total Fe 7 mg/l
Attapulgite	No discharge		No discharge	
Mine dewatering		TSS 35 mg/l		TSS 35 mg/l
Montmorillonite	No discharge		No discharge	
Mine dewatering		TSS 35 mg/l		TSS 35 mg/l
Kaolin				
Dry processing	No discharge		No discharge	
Wet processing	Turbidity 50 JTU TSS 45 mg/l Zn 0.25 mg/l	Turbidity 100 JTU TSS 90 mg/l Zn 0.50 mg/l	Turbidity 50 JTU TSS 45 mg/l Zn 0.25 mg/l	Turbidity 100 JTU TSS 90 mg/l Zn 0.50 mg/l
Mine dewatering (ore slurry pumped)	Turbidity 50 JTU TSS 45 mg/l	Turbidity 100 JTU TSS 90 mg/l	Turbidity 50 JTU TSS 45 mg/l	Turbidity 100 JTU TSS 90 mg/l
Mine dewatering (ore dry transported)		TSS 35 mg/l		TSS 35 mg/l

Ball Clay				
Dry processing	No discharge		No discharge	
Wet processing	No discharge		No discharge	
Mine dewatering		TSS 35 mg/l		TSS 35 mg/l
Feldspar				
Non-Flotation plants	No discharge		No discharge	
Flotation plants***	TSS 0.6 kg/kkg F 0.175 kg/kkg	TSS 1.2 kg/kkg F 0.35 kg/kkg	TSS 0.6 kg/kkg F 0.13 kg/kkg	TSS 1.2 kg/kkg F 0.26 kg/kkg
Mine dewatering		TSS 30 mg/l		TSS 30 mg/l
Kyanite	No discharge		No discharge	
Mine dewatering		TSS 35 mg/l		TSS 35 mg/l
Magesite	No discharge		No discharge	
Shale and Common Clay	No discharge		No discharge	
Mine dewatering		TSS 35 mg/l		TSS 35 mg/l
Aplite	No discharge		No discharge	
Mine dewatering		TSS 35 mg/l		TSS 35 mg/l
Talc, Steatite, Soapstone and Pyrophyllite				
Dry processing & Washing plants	No discharge		No discharge	
Flotation and HMS plants	TSS 0.5 kg/kkg	TSS 1.0 kg/kkg	TSS 0.3 kg/kkg	TSS 0.6 kg/kkg
Mine dewatering		TSS 30 mg/l		TSS 30 mg/l
Garnet	TSS 30 mg/l	TSS 60 mg/l	TSS 30 mg/l	TSS 60 mg/l
Tripoli	No discharge		No discharge	
Mine dewatering		TSS 30 mg/l		TSS 30 mg/l
Diatomite	No discharge		No discharge	
Mine dewatering		TSS 30 mg/l		TSS 30 mg/l
Graphite (process and Mine dewatering)	TSS 10 mg/l Total Fe 1 mg/l	TSS 20 mg/l Total Fe 2 mg/l	TSS 10 mg/l Total Fe 1 mg/l	TSS 20 mg/l Total Fe 2 mg/l
Jade	No discharge		No discharge	
Novaculite	No discharge		No discharge	

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pH 6-9 for all subcategories
No discharge - No discharge of process waste water pollutants
kg/kkg - kg of pollutant/kkg of product
* standard is to apply as net if oxidation ditches are used and intake is from the same navigable water as the discharge.
** standards are to be applied as net if discharge is to the same navigable water as brine intake
*** kg of pollutant/kkg of ore processed
BPCTCA - best practicable control technology currently available
BATEA - best available technology economically achievable
NSPS - new source performance standard

SECTION III

INTRODUCTION

The United States Environmental Protection Agency (EPA) is charged under the Federal Water Pollution Control Act Amendments of 1972 with establishing effluent limitations which must be achieved by point sources of discharge into the navigable waters of the United States. Section 301(b) of the Act requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) of the Act. Section 306 of the Act requires the achievement by new sources of a Federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants. Section 304(b) of the Act requires the Administrator to publish within one year of enactment of the Act regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operating methods and other alternatives. Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b) (1) (A) of the Act, to propose regulations establishing Federal standards of performances for new sources within such categories. The Administrator published in the Federal Register of January 16, 1973 (38 F.R. 1624), a list of 27

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source categories. Publication of an amended list on October 16, 1975 in the Federal Register constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the mineral mining and processing industry.

The products covered in this report are listed below with their SIC designations:

Dimension stone (1411)
Crushed stone (1422, 1423, 1429, 1499)
Construction sand and gravel (1442)
Industrial sand (1446)
Gypsum (1492)
Asphaltic Minerals (1499)
Asbestos and Wollastonite (1499)
Lightweight Aggregates (1499)
Mica and Sericite (1499)
Barite (1472 and 3295)
Fluorspar (1473 and 3295)
Salines from Brine Lakes (1974)
Borax (1474)
Potash (1474)
Trona Ore (1474)
Phosphate Rock (1475)
Rock Salt (1476)
Sulfur (1477)
Mineral Pigments (1479)
Lithium Minerals (1479)
Sodium Sulfate (1474)
Bentonite (1452)
Fire Clay (1453)
Fuller's Earth (1454)
Kaolin and Ball Clay (1455)
Feldspar (1459)
Kyanite (1459)
Magnesite (1459)
Shale and other clay minerals, N.E.C. (1459)
Talc, Soapstone and Pyrophyllite (1496)
Natural abrasives (1499)
Diatomite mining (1499)
Graphite (1499)
Miscellaneous non-metallic minerals,
  N.E.C. (1499)

Some of the above minerals which are processed only (SIC 3295) are also included.

The data for identification and analyses were derived from a number of sources. These sources included EPA research information, published literature, qualified technical consultation, on-site visits and interviews at numerous mining and processing facilities throughout the U.S., interviews and meetings with various trade associations, and interviews and meetings with various regional offices of the EPA. Table 2 summarizes the data base for the various subcategories in this volume. The 1972 production and employment figures in Table 3 were derived either from the Bureau of the Census (U.S. Department of Commerce) publications or the Commodity Data Summaries (1974) Appendix I to Mining and Minerals Policy, Bureau of Mines, U.S. Department of the Interior.

DIMENSION STONE (SIC 1411)

Rock which has been specially cut or shaped for use in buildings, monuments, memorial and gravestones, curbing, or other construction or special uses is called dimension stone. Large quarry blocks suitable for cutting to specific dimensions are also classified as dimension stone. The principal dimension stones are granite, marble, limestone, slate, and sandstone. Less common are diorite, basalt, mica schist, quartzite, diabase and others.

Terminology in the dimension stone industry is somewhat ambiguous and frequently does not correspond to the same terms used in mineralogical rock descriptions. Dimension granites include not only true granite, but many other types of igneous and metamorphic rocks such as quartz diorites, syenites, quartz porphyries, gabbros, schists, and gneisses. Dimension marble may be used as a term to describe not only true marbles, which are metamorphosed limestones, but also any limestone that will take a high polish. Many other rocks such as serpentines, onyx, travertines, and some granites are frequently called marble by the dimension stone industry. Hard cemented sandstones are sometimes called quartzite although they do not specifically meet the mineralogical definition.

Many of the States possess dimension stone of one kind or other, and many have one or more producing operations. However, only a few have significant operations. These are as follows:

Granite - Minnesota
- Georgia
- Vermont
- Massachusetts
- South Dakota

TABLE 2

DATA BASE

Subcategory	No. Plants	No Plants		
		Visited	Data Available	Sampled
Dimension Stone	194	20	20	5
Crushed Stone	4800			
Dry		5	52	*
Wet		26	130	9
Flotation	8	2	3	1
Shell Dredging	50	4	4	0
Construction Sand Gravel				
Dry	750	0	50	*
Wet	4,250	46	100	15
Dredging (on-land)	50	8	15	0
Dredging (on-board)	100	3	25	0
Industrial Sand				
Dry	20	0	5	*
Wet	130	3	10	2
Flotation	17	4	10	2
Acid Leaching	3	3	3	0
Flotation (HF)	1	1	1	1
Gypsum				
Dry	73	5	54	2
Wet Scrubbing	5	1	8	1
HMS	2	1	2	*
Asphaltic Minerals				
Bituminous Limestone	2	0	2	*
Oil Impreg.Diatomite	1	1	1	*
Gilsonite	1	1	1	1
Asbestos				
Dry	4	2	4	1
Wet	1	1	1	*
Wollastonite	1	1	1	*
Lightweight Aggregates				
Perlite	13	4	4	*
Pumice	7	2	7	
Vermiculite	2	2	2	*
Mica & Sericite				
Dry	7	5	7	*
Wet	3	2	3	*
Wet Beneficiation	7	5	7	*
Barite				
Dry	9	4	8	*
Wet	14	7	14	*
Flotation	4	3	4	1
Fluorspar				
HMS	6	4	6	*
Flotation	6	4	5	2
Drying and Pelletizing	2	1	2	*

Salines from Brine Lakes	3	3	3	*
Borax	1	1	1	*
Potash	5	4	5	*
Trona Ore	4	2	4	*
Phosphate Rock				
Eastern	22	21	20	3
Western	6	6	6	2
Rock Salt	21	11	15	3
Sulfur				
Anhydrite	2	1	2	*
On-Shore	9	7	9	5
Off-Shore	2	1	1	1
Mineral Pigments	11	3	3	*
Lithium Minerals	2	2	2	2
Sodium Sulfate	6	2	2	*
Bentonite	37	2	2	*
Fire Clay	81	9	9	*
Fuller's Earth				
Attapulgite	10	4	5	2
Montmor.	4	3	3	3
Kaolin				
Dry		4	4	*
Wet	37 total	6	7	0
Ball Clay	12	4	4	0
Feldspar				
Wet	5	5	5	5
Dry	2	2	2	*
Kyanite	3	2	2	*
Magnesite	1	1	1	*
Shale and Common Clay	129	10	20	*
Aplite	2	2	2	*
Talc Minerals				
Dry	27	12	20	*
Washing	2	1	2	*
HMS, Flotation	4	4	4	4
Natural Abrasives				
Garnet	3	2	2	0
Tripoli	4	2	4	*
Diatomite	9	3	3	*
Graphite	1	1	1	0
Misc. Minerals				
Jade	est. 10	1	1	*
Novaculite	1	1	1	*
Total	11,019	312	735	77

*There is no discharge of process waste water in the subcategories under normal operating conditions.

TABLE 3
Production and Employment

SIC Code	Product	1972 Production 1000 kkg	 1000 tons	Employment
1411	Dimension stone-limestone	542	598	2,000 combined
1411	Dimension stone-granite	357	394	SIC 1411
1411	Dimension stone-other*	559	616	
1422	Crushed & broken stone-limestone	542,400	598,000	29,400
1423	Crushed & broken stone granite	95,900	106,000	4,500
1429	Crushed & broken stone NEC	113,000	124,600	7,400
1499	Crushed & broken stone shell	19,000	20,900	Unknown
1442	Construction sand & gravel	650,000	717,000	30,300
1446	Industrial sand	27,120	29,999	4,400
1492	Gypsum	11,200	12,330	2,900
1499	Bituminous limestone	1,770	1,950	Unknown
1499	Oil-impregnated diatomite	109	120	Unknown
1499	Gilsonite	45	50	Unknown
1499	Asbestos	120	132	400
1499	Wollastonite	63	70	70
1499	Perlite	589	649	100
1499	Pumice	3,460	3,810	525
1499	Vermiculite	306	337	225
1499	Mica	145	160	75
1472	Barite	822	906	1,025
1473	Fluorspar	228	251	270
1474	Borates	1,020	1,120	1,800
1474	Potash (K2) equiv.	2,410	2,660	1,200
1474	Soda Ash (trona only)	2,920	3,220	1,070
1474	Sodium sulfate	636	701	100
1475	Phosphates	37,000	40,800	4,200
1476	Salt (mined only)	12,920	14,200	2,800
1477	Sulfur (Frasch)	7,300	8,040	2,900
1479	Mineral pigments	63	70	Unknown
1479	Lithium minerals	Withheld		approx. 250
1452	Bentonite	2,150	2,767	900
1453	Fire clay	3,250	3,581	500
1454	Fuller's earth	896	988	1,200
1455	Kaolin	4,810	5,318	3,900**
1455	Ball clay	612	675	
1459	Feldspar	664	732	450
1459	Kyanite	Est. 108	Est. 120	165
1459	Magnesite	Withheld		Unknown
1459	Aplite	190	210	Unknown
1459	Crude common clay	41,840	46,127	2,600
1496	Talc			
1496	Soapstone	1,004		950
1496	Pyrophyllite			
1499	Abrasives			
	Garnet	17	19	Unknown
	Tripoli	80	88	Unknown
1499	Diatomite	522	576	500
1499	Graphite	Withheld		54
1499	Jade	.107	.118	Unknown
1499	Novaculite	Withheld		15

*Sandstone, marble, et al
**Includes ball clay

Marble	-	Georgia
	-	Vermont
	-	Minnesota (dolomite)
Limestone	-	Indiana
	-	Wisconsin
Slate	-	Vermont
	-	New York
	-	Virginia
	-	Pennsylvania
Sandstone, Quartz, and Quartzite	-	Pennsylvania Ohio New York

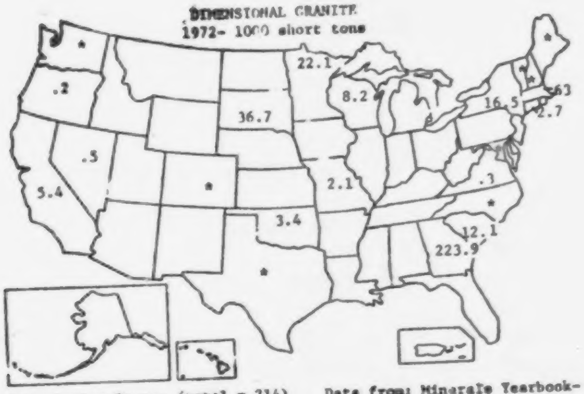
Figure 1 gives the U. S. production on a state basis for granite, limestone, sandstone, quartz and quartzite which are the principal stones quarried as shown in Table 4. There are less than 500 dimension stone mining activities in the U.S. Present production methods for dimension stone range from the inefficient and antiquated to the technologically modern. Quarrying methods include the use of various combinations of wire saws, jet torches, channeling machines, drilling machines, wedges, and broaching tools. The choice of equipment mix depends on the type of dimension stone, size and shape of deposit, production capacity, labor costs, financial factors, and management attitudes.

Blasting with a low level explosive, such as black powder, is occasionally done. Blocks cut from the face are sawed or split into smaller blocks for ease in transportation and handling. The blocks are taken to processing facilities, often located at the quarry site, for final cutting and finishing operations. Stone finishing equipment includes: (a) gang saws (similar to large hack saws) used with water alone or water with silicon carbide (SiC) abrasive added, and recently, with industrial diamond cutting edges; (b) wire saws used with water alone, or with water and quartz sand, or water with SiC; (c) diamond saws; (d) profile grinders; (e) guillotine cutters; (f) pneumatic actuated cutting tools (chisels); (g) sand blasting and shot peening; and (h) polishing mills.

FIGURE 1

DIMENSION STONE DISTRIBUTION

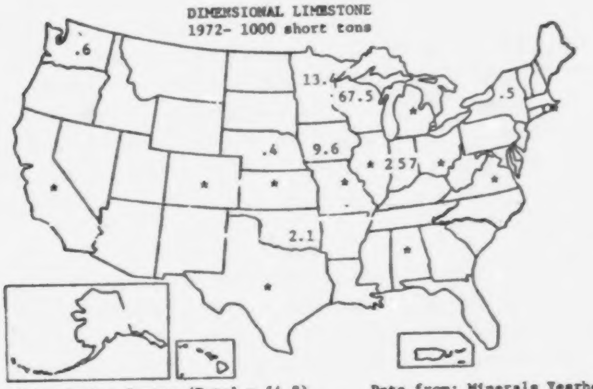
DIMENSIONAL GRANITE
1972- 1000 short tons


*
.2
.5
5.4
*
36.7
22.1
8.2
2.1
3.4
*
*
*
16.5
63
2.7
.3
*
12.1
223.9

* Producing States (total = 214)
National Total = 621.2

Data from: Minerals Yearbook- 1972,
Vol. I, Table 5, p. 1164

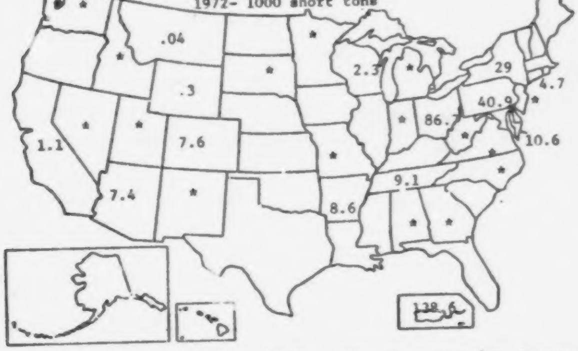
DIMENSIONAL LIMESTONE
1972- 1000 short tons


.6
*
*
.4
*
13.4
67.5
9.6
*
* 257
*
*
*
.5
*
2.1
*
*

* Producing States (Total = 54.8)
National Total = 411.1 (excluding P.R.)

Data from: Minerals Yearbook
1972, Vol.I, Table 6,p. 1164

DIMENSIONAL SANDSTONE,
QUARTZ, QUARTZITE
1972- 1000 short tons


*
.04
*
.3
*
*
1.1
*
*
7.6
7.4
*
*
2.3
*
*
86.7
29
4.7
40.9
*
10.6
*
*
*
9.1
8.6
*
*
138.6

* Producing States (Total = 22.3)
National Total = 230.7

Data from: Minerals Yearbook-1972
Vol.I, Table 7, p.1165.

TABLE 4

DIMENSION STONE BY USE AND KIND OF STONE

(1972)

Kind of stone and use	1000 short tons
GRANITE	
Rough:	
Architectural	46
Construction	54
Monumental	287
Other rough stone	--
Dressed:	
Cut	--
Sawed	14
House stone veneer	6
Construction	10
Monumental	33
Curbing	130
Flagging	--
Paving blocks	--
Other dressed stone	42
Total	621
Value ($1000)	42,641
LIMESTONE AND DOLOMITE	
Rough:	
Architectural	175
Construction	56
Flagging	18
Other rough stone	1
Dressed:	
Cut	49
Sawed	30
House stone veneer	68
Construction	12
Flagging	2
Other dressed stone	1
Total	411
Value ($1000)	14,378
MARBLE	
Rough: Architectural	9
Dressed:	
Cut	21
Sawed	5
House stone veneer	9
Construction and Monumental	27
Total	71
Value ($1000)	16,541
SANDSTONE, QUARTZ & QUARTZITE	
Rough:	
Architectural	42
Construction	74
Flagging	18
Other rough stone	1
Dressed:	
Cut	21
Curbing	--
Sawed	--
House stone veneer	27
Flagging	17
Other uses not listed	32
Total	231
Value ($1000)	7,684
SLATE	
Roofing slate	12
Millstock:	
Structural and sanitary	14
Blackboards, etc.	1
Billiard table tops	4
Total	19
Flagging	36
Other uses not listed	14
Total	80
Value ($1000)	7,404
OTHER STONE	
Rough:	
Architectural	14
Construction	43
Dressed:	
Cut	2
Construction	4
Flagging	--
Structural and sanitary purposes	--
Total	66
Value ($1000)	1,964
TOTAL STONE	
Rough:	
Architectural	286
Construction	239
Monumental	287
Flagging	36
Other rough stone	2
Dressed:	
Cut	117
Sawed	65
House stone veneer	110
Construction	32
Roofing (slate)	12
Millstock (slate)	19
Monumental	65
Curbing	130
Flagging	61
Other uses not listed	31
Total	1,490
Value ($1000)	90,763

Minerals Yearbook, 1972, U.S. Department of the Interior, Bureau of Mines

CRUSHED STONE (SIC 1422, 1423 and 1429)

This stone category pertains to rock which has been reduced in size after mining to meet various consumer requirements. As with dimension stone, the terminology used by the crushed stone producing and consuming industries is not consistent with mineralogical definitions. Usually all of the coarser grained igneous rocks are called granite. The term traprock pertains to all dense, dark, and fine-grained igneous rocks. Quartzite may describe any siliceous-cemented sandstone whether or not it meets the strict mineralogical description. Approximately three-fourths of all crushed stone is limestone.

Riprap is large irregular stone used chiefly in river and harbor work and to protect highway embankments. Fluxing stone is limestone, usually 4 to 6 inches in cross section, which is used to form slag in blast furnaces and other metallurgical processes. Terrazzo is sized material, usually marble or limestone, which is mixed with cement for pouring floors and is smoothed to expose the chips after the floor has hardened. Some quartzose rock is also used for flux. Stucco dash consists of white or brightly colored stone, 1/8 to 3/8 inches in size, for use in stucco facing. Ground limestone is used to significantly reduce the acidity of soils.

The crushed stone industry is widespread and varied in size of facilities and types of material produced. The size of individual firms varies from small independent producers with single facilities to large diversified corporations with 50 or more crushed stone facilities as well as other important interests. Facility capacities range from less than 22,700 kkg/yr (25,000 tons/yr) to about 13.6 million kkg/yr (15 million tons/yr). As Table 5 shows only about 5.2 percent of the commercial facilities are of a 816,000 kkg (900,000 ton) capacity or larger, but these account for 39.5 percent of the total output. At the other extreme, facilities of less than 22,700 kkg (25,000 ton) annual capacity made up 33.3 percent of the total number but produce only 1.3 percent of the national total. Geographically, the facilities are widespread with all States reporting production. In general, stone output of the individual States correlates with population and industrial activity as shown by Figure 2. This is true because of the large cost of shipment in relation to the value of the crushed stone.

TABLE 5

SIZE DISTRIBUTION OF CRUSHED STONE PLANTS*

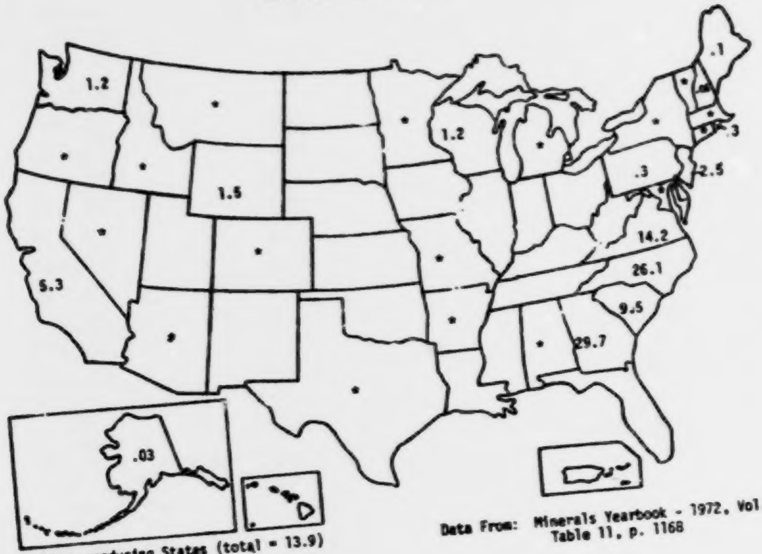
ANNUAL PRODUCTION TONS	NUMBER OF QUARRIES	TOTAL ANNUAL PRODUCTION 1000 TONS	PERCENT OF TOTAL
< 25,000	1,600	13,603	1.3
25,000 - 49,999	600	24,221	2.3
50,000 - 74,999	339	20,485	1.9
75,000 - 99,999	253	21,941	2.1
100,000 - 199,999	634	90,974	8.6
200,000 - 299,999	308	75,868	7.2
300,000 - 399,999	233	80,946	7.6
400,000 - 499,999	182	80,956	7.7
500,000 - 599,999	126	68,903	6.5
600,000 - 699,999	98	62,730	5.9
700,000 - 799,999	76	56,694	5.4
800,000 - 899,999	51	42,718	4.0
> 900,000	248	418,502	39.5
TOTAL	4,808	1,058,541	100.0

* U.S. Deaprtment of the Interior
Bureau of Mines
Division of Nonmetallic Minerals
1973

FIGURE 2

CRUSHED STONE DISTRIBUTION

CRUSHED GRANITE
1972/1,000,000 short tons

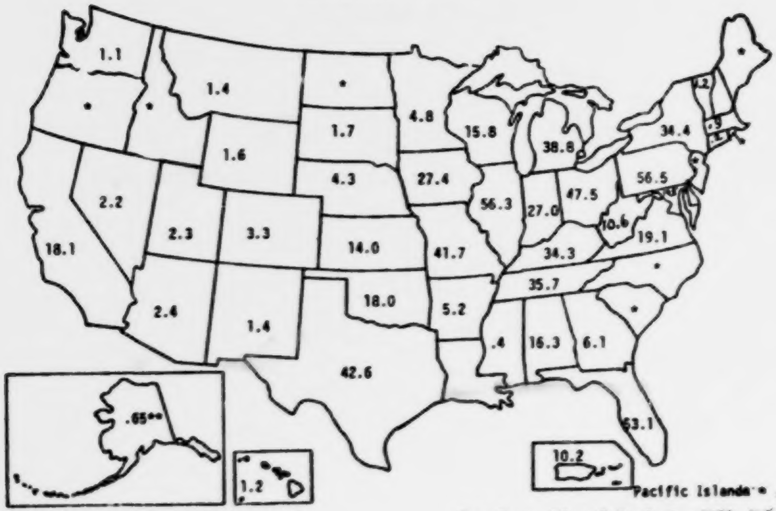


1.2
1.5
5.3
.03
1.2
.3
.1
.3
2.5
14.2
26.1
9.5
29.7

Data From: Minerals Yearbook - 1972, Vol. I
Table 11, p. 1168

* Other producing States (total = 13.9)
National Total = 106.3

CRUSHED LIMESTONE
AND DOLOMITE
1972/1,000,000 short tons



1.1
1.4
1.7
4.8
15.8
38.8
.2
.9
34.4
1.6
4.3
27.4
56.5
2.2
56.3
27.0
47.5
10.6
19.1
18.1
2.3
3.3
14.0
41.7
34.3
35.7
18.0
5.2
2.4
1.4
.4
16.3
6.1
42.6
.65**
53.1
10.2
1.2

Pacific Islands* = .9

** Total stone - crushed & dimensional
* Other producing States (total = 8.2)
National total (excluding P.R. & territories) = 663.3

Data From: Mineral Yearbook - 1972, Vol. I
Table 13, p. 1170

Most crushed and broken stone is presently mined from open quarries, but in many areas underground mining is becoming more frequent. Surface mining equipment varies with the type of stone, the production capacity needed, size and shape of deposits, estimated life of the operation, location of the deposit with respect to urban centers, and other important factors. Ordinarily, drilling is done with tricone rotary drills, long-hole percussion drills including "down the hole" models, and churn drills. Blasting in smaller operations may still be done with dynamite, but in most sizable operations ammonium nitrate-fuel oil mixtures (AN/FO) are used, which are much lower in cost. Secondary breakage increasingly is done with mechanical equipment such as drop hammers to minimize blasting in urban and residential areas.

Underground operations are becoming more common as the advantages of such facilities are increasingly recognized by the producers. Underground mines can be operated on a year-round, uninterrupted basis; do not require extensive removal of overburden; do not produce much if any waste requiring subsequent disposal; require little surface area which becomes of importance in areas of high land cost and finally, greatly reduce the problems of environmental disturbance and those of rehabilitation of mined-out areas. An additional benefit from underground operations, as evidenced in the Kansas City area, is the value of the underground storage space created by the mine - in many cases the sale or rental of the space produces revenue exceeding that from the removal of the stone.

Loading and hauling equipment has grown larger as increasing demand for stone has made higher production capacities necessary. Track-mounted equipment is still used extensively but pneumatic-tire-mounted hauling equipment is predominant.

Crushing and screening facilities have become larger and more efficient, and extensive use is made of belt conveyors for transfer of material from the pits to the loading-out areas. Bucket elevators are used for lifting up steep inclines. Primary crushing is often done at or near the pit, usually by jaw crushers or gyratories, but impact crushers and special types may be used for nonabrasive stone, and for stone which tends to clog the conventional crushers. For secondary crushing a variety of equipment is used depending on facility size, rock type, and other factors. Cone crushers and gyratories are the most common types. Impact types including hammer mills are often used where stone is not too abrasive. For fine grinding to produce stone sand, rod mills predominate.

For screening, inclined vibrating types are commonly used in permanent installations, while horizontal screens, because they require less space, are used extensively in portable facilities. For screening large sizes of crushed stone, heavy punched steel plates are used, while woven wire screens are used for smaller material down to about one-eighth of an inch. Air and hydraulic separation and classifying equipment is ordinarily used for the minus 1/8 inch material.

Storage of finished crushed stone is usually done in open areas except for the small quantities that go to the load-out bins. In the larger and more efficient facilities the stone is drawn out from tunnels under the storage piles, and the equipment is designed to blend any desired mixture of sizes that may be needed.

Oyster shells, being made of very pure calcium carbonate, are dredged for use in the manufacture of lime and cement. The industry is large and active along the Gulf Coast, especially at New Orleans, Lake Charles, Houston, Freeport, and Corpus Christi. In Florida, oyster shell was recovered from fossil beds offshore on both Atlantic and Gulf coasts. Production in 1957 amounted to 1,364,000 kkg (1,503,964 tons), used principally for road metal and a small amount as poultry grit. This figure included coquina, a cemented shell rock of recent but not modern geological time, which is dredged for the manufacture of cement near Bunnell in Flagler County. It is used widely on lightly traveled sand roads along the east coast. Clam shells used to be dredged from fresh water streams in midwestern states for the manufacture of buttons, but the developments in the plastics industry have impacted heavily. Table 6 gives a breakdown of the end uses of crushed stone. The majority of crushed stone is used in road base, cement and concrete.

CONSTRUCTION SAND AND GRAVEL (SIC 1442)

Sand and gravel are products of the weathering of rocks and thus consist predominantly of silica but often contain varying amounts of other minerals such as iron oxides, mica and feldspar. The term sand is used to describe material whose grain size lies within the range of 0.065 and 2 mm and which consists primarily of silica but may also include fine particles of any rocks, minerals and slags. Gravel consists of naturally occurring rock particles larger than about 4 mm but less than 64 mm in diameter. Although silica usually predominates in gravel, varying amounts of other rock constituents such as mica, shale, and feldspar are often present. Silt is a term used to describe material finer than sand, while cobbles and boulders are larger than

TABLE 6

USES OF CRUSHED STONE

Kind of stone and use	Quantity (1000 tons)
CALCAREOUS MARL	
Agricultural purposes	133
Cement manufacture	2,517
Other uses	--
Total	2,650
Value ($1000)	3,598
GRANITE	
Agricultural purposes	--
Concrete aggregate (coarse)	18,579
Bituminous aggregate	16,088
Macadam aggregate	3,966
Dense graded road base stone	37,877
Surface treatment aggregate	5,695
Unspecified construction aggregate and roadstone	10,048
Riprap and jetty stone	4,036
Railroad ballast	6,162
Filter stone	--
Fill	97
Other uses	3,718
Total	106,266
Value ($1000)	182,930
LIMESTONE AND DOLOMITE	
Agricultural purposes	27,140
Concrete aggregate (coarse)	100,173
Bituminous aggregate	49,977
Macadam	26,993
Dense graded road base stone	139,257
Surface treatment aggregate	38,704
Unspecified construction aggregate and roadstone	71,647
Riprap and jetty stone	12,935
Railroad ballast	7,250
Filter stone	339
Manufactured fine aggregate (stone sand)	4,752
Terrazzo and exposed aggregate	124
Cement manufacture	101,304
Lime manufacture	28,858
Dead-burned dolomite	1,670
Ferrosilicon	1,030
Flux stone	24,728
Refractory stone	395
Chemical stone for Alkali works	4,199
Special uses and products	876
Mineral fillers, extenders, and whiting	2,984
Chemicals	635
Fill	4,243
Glass	1,794
Sugar refining	560
Other uses	16,930
Total	671,496
Value ($1000)	1,090,707
MARBLE	
Agricultural purposes	44
Macadam aggregate	83
Concrete aggregate (coarse)	--
Dense graded road base stone	--
Unspecified construction aggregate and roadstone	862
Riprap and jetty stone	--
Filter stone	--
Manufactured fine aggregate (stone sand)	--
Terrazzo and exposed aggregate	203
Mineral fillers, extenders, and whiting	1,047
Other uses	8
Total	2,247
Value ($1000)	25,005
SANDSTONE, QUARTZ, AND QUARTZITE	
Concrete aggregate (coarse)	2,092
Bituminous aggregate	1,613
Macadam aggregate	351
Dense graded road base stone	8,744
Surface treatment aggregate	951
Unspecified construction aggregate and roadstone	3,290
Riprap and jetty stone	2,213
Railroad ballast	1,014
Filter stone	52
Manufactured fine aggregate (stone sand)	343
Terrazzo and exposed aggregate	23
SANDSTONE, QUARTZ, AND QUARTZITE (continued)	
Cement and lime manufacture	522
Ferrosilicon	227
Flux stone	1,102
Refractory stone	211
Abrasives	45
Glass	925
Other uses	3,100
Total	26,817
Value ($1000)	57,994
SHELL	
Concrete aggregate (coarse)	--
Dense graded road base stone	1,675
Unspecified construction aggregate and roadstone	3,281
Cement and lime manufacture	5,675
Other uses	5,98[illegible]
Total	16,610
Value ($1000)	29,571
TRAPROCK	
Agricultural purposes	444
Concrete aggregate (coarse)	6,643
Bituminous aggregate	11,469
Macadam aggregate	1,438
Dense graded road base stone	19,361
Surface treatment aggregate	5,341
Unspecified construction aggregate and roadstone	23,811
Riprap and jetty stone	3,623
Railroad ballast	2,332
Filter stone	117
Manufactured fine aggregate (stone sand)	231
Fill	1,686
Other uses	3,966
Total	80,462
Value ($1000)	170,823
OTHER STONE	
Concrete aggregate (coarse)	1,159
Bituminous aggregate	2,202
Macadam aggregate	278
Dense graded road base stone	3,051
Surface treatment aggregate	591
Unspecified construction aggregate and roadstone	2,911
Riprap and jetty stone	1,738
Railroad ballast	--
Mineral fillers, extenders and whiting	--
Fill	578
Other uses	1,789
Total	14,298
Value ($1000)	24,442
TOTAL STONE	
Agricultural purposes	23,393
Concrete aggregate (coarse	133,471
Bituminous Aggregate	82,560
Macadam aggregate	33,110
Dense graded road base stone	210,013
Surface treatment aggregate	51,943
Unspecified construction aggregate and roadstone	113,406
Riprap and jetty stone	24,560
Railroad ballast	18,021
Filter stone	636
Manufactured fine aggregate (stone sand)	5,869
Terrazzo and exposed aggregate	402
Cement manufacture	108,857
Lime manufacture	30,051
Dead-burned dolomite	1,670
Ferrosilicon	1,257
Flux stone	25,830
Refractory stone	605
Chemical stone for alkali works	4,199
Special uses and products	1,071
Mineral fillers, extenders and whiting	4,423
Fill	6,630
Glass	2,718
Expanded slate	1,270
Other uses	31,394
Total	922,361
Value ($1000)	1,592,569

Minerals Yearbook, 1972, U.S. Department of the Interior
Bureau of Mines

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gravel. The term "granules" describes material in the 2 to 4 mm size range. The descriptive terms and the size ranges are somewhat arbitrary although standards have to some extent been accepted. For most applications of sand and gravel there are specifications for size, physical characteristics, and chemical composition. For construction uses, the specifications depend on the type of construction (concrete or bituminous roads, dams, and buildings) the geographic area, architectural standards, climate, and the type and quality of sand and gravel available.

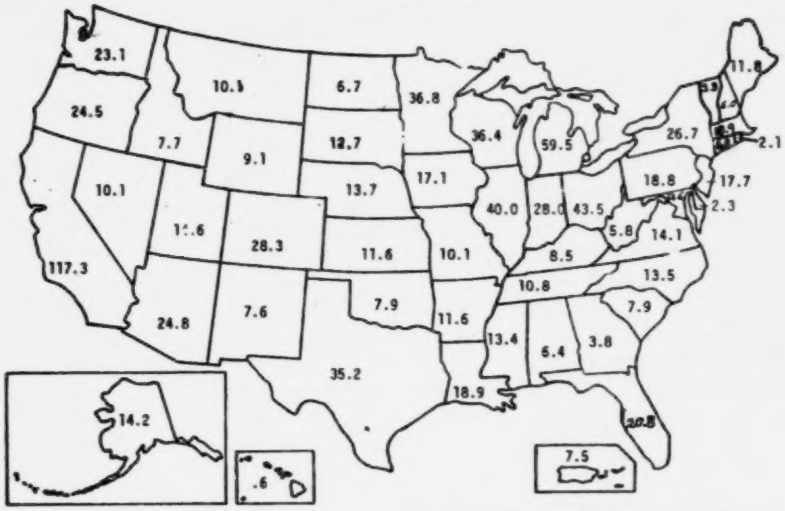
In summary for the glaciated areas in the northern States, and for a hundred miles or more south of the limit of glacial intrusion, the principal sand and gravel resources consist of various types of outwash glacial deposits and glacial till. Marine terraces, both ancient and recent are major sand and gravel sources in the Atlantic and Gulf Coastal Plains. River deposits are the most important sand and gravel sources in several of the Southeastern and South Central States. Abundant sand and gravel resources exist in the mountainous areas and the drainage from the mountains has created deposits at considerable distances from the initial sources. Great Plains sand and gravel resources consist mainly of stream-worked material from existing sediments. On the West Coast, deposits consist of alluvial fans, river deposits, terraces, beaches, and dunes. Figure 3 shows the production and facility distribution for the United States.

The crushed stone and sand and gravel industries, on the basis of tonage are the largest nonfuel mineral industries. Because of their widespread occurrence and the necessity for producing sand and gravel near the point of use, there are more than 5,000 firms engaged in commercial sand and gravel output, with no single firm being large enough to dominate the industry. Facility sizes range from very small producers of pit-run material to highly automated permanent installations capable of supplying as much as 3.6 million kkg (4 million tons) yearly of closely graded and processed products; the average commercial facility capacity is about 108,000 kkg/yr (120,000 tons/yr). As seen from Table 7 about 40 percent of all commercial facilities are of less than 22,600 kkg (25,000 tons) capacity, but together these account for only 4 percent of the total commercial production. At the other extreme, commercial operations with production capacities of more than 907,000 kkg (1 million tons) account for less than 1 percent of the total number of facilities and for 12 to 15 percent of the commercial production.

FIGURE 3

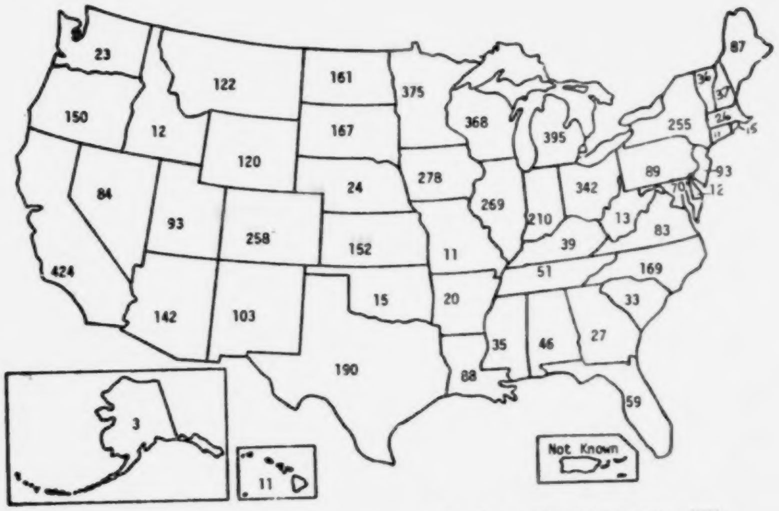
SAND AND GRAVEL DISTRIBUTION

PRODUCTION
1972/1,000,000 short tons


23.1
10.1
6.7
36.8
11.8
24.5
7.7
9.1
12.7
36.4
59.5
26.7
2.1
10.1
13.7
17.1
18.8
17.7
40.0
28.0
43.5
2.3
11.6
28.3
11.6
10.1
5.8
14.1
8.5
117.3
10.8
13.5
7.9
24.8
7.6
11.6
7.9
13.4
6.4
3.8
35.2
18.9
20.8
14.2
.6
7.5

National Total (excluding P.R.) = 913.2

Data From: Minerals Yearbook - 1972, Vol. I
Table 3, p. 1111-1112
Bureau of Mines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122
161
375
87
34
37
150
12
167
368
395
26
255
15
120
278
11
24
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93
84
269
342
70
12
93
258
210
13
152
11
39
83
424
51
169
15
20
33
142
103
35
46
27
190
88
59
3
Not Known
11

Data From: Minerals Yearbook - 1972
Vol II
Bureau of Mines

TABLE 7

Size Distribution of Sand and Gravel Plants

Annual Production (short tons)	Plants Number	Production Thousand short tons	 Percent of total
Less than 25,000	1,630	17,541	2.2
25,000 to 50,000	850	30,508	3.9
50,000 to 100,000	957	68,788	8.8
100,000 to 200,000	849	121,304	15.4
200,000 to 300,000	400	97,088	12.4
300,000 to 400,000	217	75,157	9.6
400,000 to 500,000	134	59,757	7.6
500,000 to 600,000	79	42,924	5.5
600,000 to 700,000	71	46,036	5.9
700,000 to 800,000	56	41,860	5.3
800,000 to 900,000	26	22,310	2.8
900,000 to 1,000,000	27	25,666	3.3
1,000,000 and over	88	136,850	17.3
Total	5,384	785,788	100.0

Minerals Yearbook, 1972, U.S. Department of the Interior, Bureau of Mines, Vol I, page 1120

Geographically the sand and gravel industry is concentrated in the large rapidly expanding urban areas and on a transitory basis, in areas where highways, dams, and other large-scale public and private works are under construction. Three-fourths of the total domestic output of sand and gravel is by commercial firms, and one-fourth by Government-and-contractor operations.

California leads in total sand and gravel production with a 1972 output more than double that of any other State. Production for the State in 1968 was 113 million kkg (125 million tons), or 14 percent of the national total. Three of the 10 largest producing firms are located in California. The next five producing States with respect to total output all border on the Great Lakes, where ample resources, urban and industrial growth, and low-cost lake transportation are all favorable factors.

Mining equipment used varies from small, simple units such as tractor-mounted high-loaders and dump trucks to sophisticated mining systems involving large power shovels, draglines, bucket-wheel excavators, belt conveyors and other components. Sand and gravel is also dredged from river and lake bottoms rich in such deposits.

Processing may consist of simple washing to remove clay and silt and screening to produce two or more products, or it may involve more complex heavy medium separation of slate and other lightweight impurities and complex screening and crushing equipment designed to produce the optimum mix of salable sand and gravel sizes. Conveyor belts, bucket elevators, and other transfer equipment are used extensively. Ball milling is often required for production of small-size fractions of sand. Permanent installations are built where large deposits are to be operated for many years. Semiportable units are used in many pits which have an intermediate working life. Several such units can be tied together to obtain large initial production capacity or to add capacity as needed. In areas where large deposits are not available, use is made of mobile screening facilities, which can be quickly moved from one deposit to another without undue interruption or loss of production. Table 8 breaks down the end uses of sand and gravel.

INDUSTRIAL SAND (SIC 1446)

Industrial sand includes those types of silica raw materials that have been segregated and refined by natural processes into nearly monomineralic deposits and hence, by virtue of their high degree of purity, have become the sources of commodities having special and somewhat restricted

Table 8
Uses of Sand and Gravel

Use	Quantity 1000 kkg	Quantity 1000 short tons
Building		
Sand	170,329	187,794
Gravel	139,001	153,254
Paving		
Sand	119,182	131,402
Gravel	254,104	280,159
Fill		
Sand	44,050	48,567
Gravel	39,416	43,458
Railroad Ballast		
Sand	948	1,045
Gravel	2,022	2,229
Other		
Sand	8,685	9,575
Gravel	11,682	12,880
Total	789,419	870,363
Value ($1000)		1,069,374
Value ($/Quantity)	1.35	1.23

Minerals Yearbook, 1972, U.S. Department of the Interior
Bureau of Mines

commercial uses. In some instances, these raw materials occur in nature as unconsolidated quartzose sand or gravel and can be exploited and used with very little preparation and expense. More often, they occur as sandstone, conglomerate quartzite, quartz mica schist, or massive igneous quartz which must be crushed, washed, screened, and sometimes chemically treated before commodities of suitable composition and texture can be successfully prepared. Industrial silica used for abrasive purposes falls into three main categories: (a) blasting sand; (b) glass-grinding sand; and (c) stonesawing and rubbing sand. Figure 4 locates the domestic industrial sand deposits. Table 9 gives the breakdown of the uses of industrial sand.

Blasting sand is a sound closely-sized quartz sand which, when propelled at high velocity by air, water, or controlled centrifugal force, is effective for such uses as cleaning metal castings, removing paint and rust, or renovating stone veneer. The chief sources of blasting sands are in Ohio, Illinois, Pennsylvania, West Virginia, New Jersey, California, Wisconsin, South Carolina, Georgia, Florida, and Idaho.

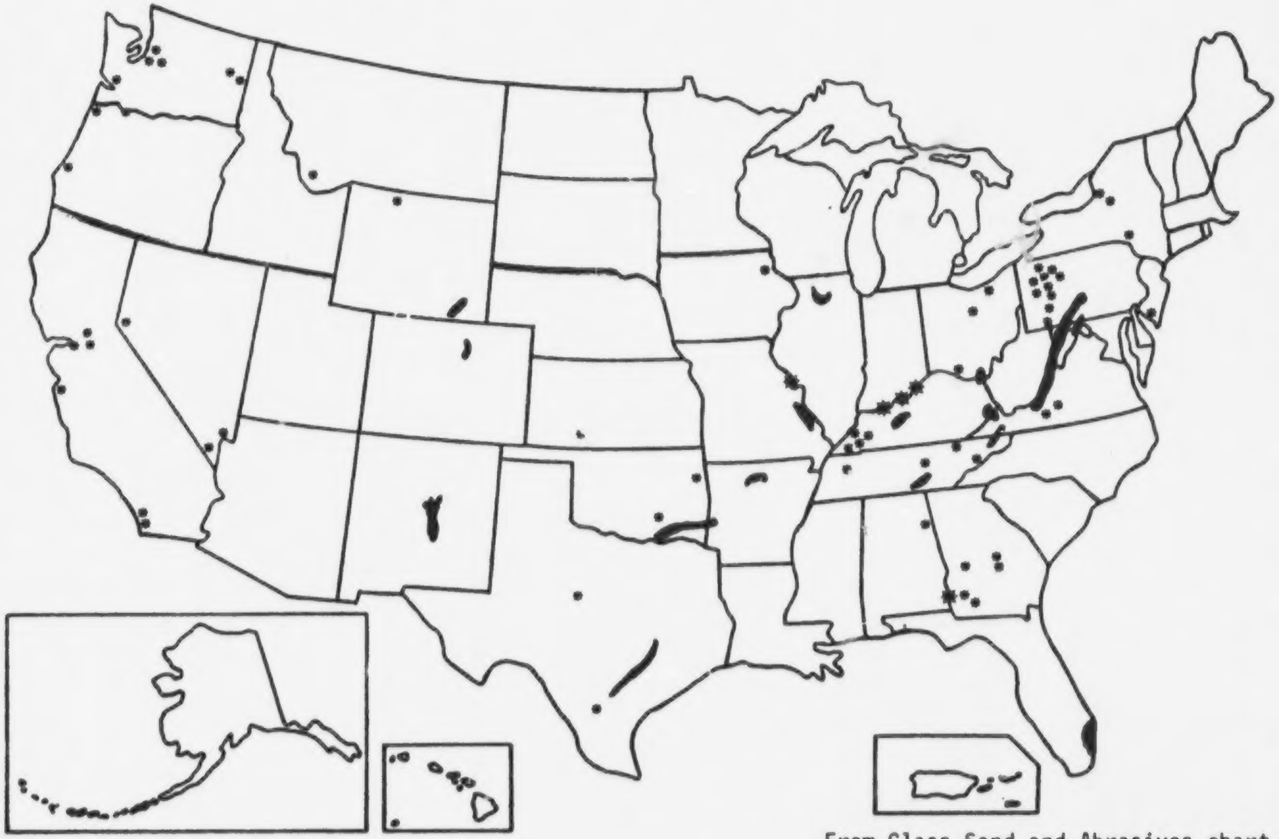
Glass-grinding sand is clean, sound, fine to medium-grained silica sand, free from foreign material and properly sized for either rough grinding or semifinal grinding of plate glass. Raw materials suitable for processing into these commodities comprise deposits of clean, sound sand, sandstone, and quartzite. As this commodity is expensive to transport sources of this material nearest to sheet and plate glass facilities are the first to be exploited.

Stonesawing and rubbing sand is relatively pure, sound, well-sorted, coarse-grained, siliceous material free from flats and fines. It is used for sawing and rough-grinding dimension stone. Neither textural nor quality specifications are rigorous on this type of material as long as it is high in free silica and no clay, mica, or soft rock fragments are present. Chert tailings, known as chats in certain mining districts, are used successfully in some regions as stonesawing and rubbing sand. River terrace sand, and glacial moraine materials, which have been washed and screened to remove oversize and fines, are often employed. Several important marble and granite producing districts are quite remote from sources of clean silica sand and are forced to adapt to less efficient sawing and grinding materials.

Glass-melting and chemical sands are quartz sands of such high purity that they are essentially monomineralic; permissible trace impurities vary according to use. Grain

FIGURE 4

INDUSTRIAL SAND DEPOSITS



From Glass Sand and Abrasives chart-pg.184
The National Atlas of The USA
USGS-1970

Table 9
Uses of Industrial Sand

Use	Quantity		Value	
	1000 kkg	1000 short tons	$/kkg	$/ton
Unground				
Glass	9821	10828	4.20	3.81
Molding	6822	7522	3.64	3.30
Grinding and polishing	238	262	3.08	2.79
Blast sand	972	1072	6.46	5.86
Fire or furnace	638	703	3.52	3.19
Engine (RR)	545	601	2.54	2.30
Filtration	212	234	5.53	5.02
Oil Hydrofrac	256	282	4.18	3.79
Other	3187	3514	3.73	3.38
Ground Sand	4092	4512	5.26	4.77
Total	26784	29530	4.20	3.81

Minerals Yearbook, 1972, U.S. Department of the Interior, Bureau of Mines shape is not a critical factor, but size frequency distribution can vary only between narrow limits. Appropriate source materials are more restricted than for any other industrial silica commodity group. Because the required products must be of superlative purity and consequently are the most difficult and expensive to prepare, they command higher prices and can be economically shipped greater distances than nearly any other class of special sand. To qualify as a commodity in this field the product must be a chemically pure quartz sand essentially free of inclusions, coatings, stains, or detrital minerals. Delivery to the customer in this highly refined state must be guaranteed and continuing uniformity must be maintained. At the present time the principal supply of raw materials for these commodities comes from two geological formations. The Oriskany quartzite of Lower Devonian age occurs as steeply dipping beds in the Appalachian Highlands. Production, in order of importance, is centered in West Virginia, Pennsylvania, and Virginia. The St. Peter sandstone of Lower Ordovician age occurs as flatlying beds in the Interior Plains and Highlands and is exploited in Illinois, Missouri, and Arkansas.

Metallurgical pebble is clean graded silica in gravel sizes that is low in iron and alumina. It is used chiefly as a component in the preparation of silicon alloys or as a flux in the preparation of elemental phosphorus. A quartzite or quartz gravel to qualify as a silica raw material must meet rigorous chemical specifications. Metallurgical gravel is no exception, and in the production of silicon alloys, purity is paramount. Such alloys as calcium-silicon, ferrosilicon, silicon-chrome, silicon copper, silicomanganese, and silicon-titanium are the principal products prepared from this material. The better deposits of metallurgical grade pebble occur principally as conglomerate beds of Pennsylvanian age, and as gravelly remnants of old river terraces developed from late Tertiary to Recent times. The significant producing area is in the Sharon conglomerate member of the Pottsville formation in Ohio. Silica pebble from the Sewanee conglomerate is produced in Tennessee for alloy and flux use. Past production for metallurgical use has come from the Olean conglomerate member of the Pottsville formation in New York, and the Sharon conglomerate member of the Pottsville formation in Pennsylvania. Production from terrace gravels is done in North Carolina, Alabama, South Carolina, and Florida in roughly decreasing order of economic importance. Marginal deposits of coarse quartzose gravel occur in Kentucky. Terrace deposits of vein quartz gravel in California have supplied excellent material for ferrosilicon use.

Industrial silica used principally for its refractory properties in the steel and foundry business is of several types: core sand, furnace-bottom sand, ganister mix, naturally bonded molding sand, processed molding sand, refractory pebble, and runner sand. A foundry sand used in contact with molten metal must possess a high degree of refractoriness; that is, it must resist sintering which would lead to subsequent adhesion and penetration at the metal-sand interface. To be used successfully as a mold or a core into which or around which molten metal is cast, it also must be highly permeable. This allows the escape of steam and gases generated by action of the hot metal upon binders and additives in the mold or core materials. Such a sand must have sufficient strength under compression, shear, and tension to retain its molded form not only in the green state at room temperature, but also after drying and baking, and later at the elevated temperatures induced by pouring. Finally, it must be durable and resist deterioration and breakdown after repeated use.

Core sand is washed and graded silica sand low in clay substance and of a high permeability, suitable for core-making in ferrous and nonferrous foundry practice. Furnace bottom sand is unwashed and partially aggregated silica sand suitable for lining and patching open hearth and electric steel furnaces which utilize an acid process. The term fire sand is often employed but is gradually going out of use. As for core sands, source materials for this commodity are quartz sands and sandstones which occur within reasonable shipping distances of steelmaking centers. Chief production centers are in Illinois, Ohio, Michigan, West Virginia, Pennsylvania, and New Jersey.

Ganister mix is a self-bonding, ramming mixture composed of varying proportions of crushed quartzose rock or quartz pebble and plastic fire clay, suitable for lining, patching, or daubing hot metal vessels and certain types of furnaces. It is variously referred to as Semi-silica or Cupola daub. As in molding sands, there are two broad classes of materials used for this purpose. One is a naturally-occuring mixture of quartz sand and refractory clay, and the other is a prepared mixture of quartz in pebble, granule, or sand sizes bonded by a clay to give it plasticity. Naturally occuring ganister mix is exploited in two areas in California and one in Illinois. The California material contains roughly 75 percent quartz sand between 50 and 200 mesh; the remaining portion is a refractory clay. However, the bulk of this commodity is produced in the East and Mid-West where the foundry and steel business is centered. A large volume is produced from pebbly phases of the Sharon conglomerate in Ohio. The Veria sandstone of Mississippian age is crushed and pelletized for this purpose in Ohio. In Pennsylvania it is prepared from the Chickies quartzite of Lower Cambrian age, although some comes from a pebbly phase of the Oriskany. In Massachusetts, a post-Carboniferous hydrothermal quartz is used and in Wisconsin, production comes from the Pre-Cambrian Baraboo quartzite.

Naturally bonded molding sand is crude silica sand containing sufficient indigenous clay to make it suitable for molding ferrous or non-ferrous castings. Natural molding sands are produced in New York, New Jersey, and Ohio. Coarse-grained naturally bonded molding sand with a high permeability suitable for steel castings is produced to some extent wherever the local demand exists. Large tonnages are mined from the Connoquenessing and Homewood sandstone members of the Pottsville formation in Pennsylvania, the St. Peter sandstone in Illinois, and the Dresbach sandstone of Upper Cambrian age in Wisconsin. Processed molding sand is washed and graded quartz sand which, when combined with appropriate bonding agents in the foundry, is suitable for use for cores and molds in ferrous and nonferrous foundries. The source materials which account for the major tonnage of processed molding sand are primarily from the St. Peter formation in Illinois and Missouri, the Oriskany quartzite in Pennsylvania and West Virginia, the basal Pottsville in Ohio and Pennsylvania, and the Tertiary sands in New Jersey.

Refractory pebble is clean graded silica in gravel sizes, low in iron and alumina, used as a raw material for superduty acid refractories. With few exceptions, bedded conglomerate and terrace gravel furnish the bulk of the raw material. Silica pebble from the Sharon conglomerate in Ohio and the Mansfield formation in Indiana are utilized. Significant production comes from a coarse phase of the Oriskany in Pennsylvania as well as from deposits of Bryn Mawr gravel in Maryland. Potential resources of conglomerate and terrace gravel of present marginal quality occur in other areas of the United States. Other quartzitic formations are currently utilized for superduty refractory work. Notable production comes from the Baraboo quartzite in Wisconsin, the Weisner quartzite in Alabama, and from quartzite beds in the Oro Grande series of sediments in California.

Runner sand is a crude coarse-grained silica sand, moderately high in natural clay bond, used to line runners and dams on the casting floor of blast furnaces. Runner sand is also used in the casting of pig iron. The term Casthouse sand also is used in the steel industry. Coal-washing sand is a washed and graded quartz sand of constant specific gravity used in a flotation process for cleaning anthracite and bituminous coal. Filter media consist of washed and graded quartzose gravel and sand produced under close textural control for removal of turbidity and bacteria from municipal and industrial water supply systems. Hydraulic-fracturing sand is a sound, rounded, light-colored quartz sand free of aggregated particles. It possesses high uniformity in specified size ranges which, when immersed in a suitable carrier and pumped under great pressure into a formation, increases fluid production by generating greater effective permeability. It is commonly referred to as Sandfrac sand in the trade.

GYPSUM (SIC 1492)

Gypsum is a hydrated calcium sulfate ($CaSO_4 \bullet 2H_2O$) generally found as a sedimentary bed associated with limestone, dolomite, shale or clay in strata deposited from early Paleozoic to recent ages. Most deposits of gypsum and anhydrite ($CaSO_4$) are considered to be chemical precipitates formed from saturated marine waters. Deposits are found over thousands of square miles with thicknesses approaching 549 meters (1800 feet), example the Castle anhydrite of Texas and New Mexico. Field evidence indicates that most deposits were originally anhydrite which was subsequently converted by surface hydration to gypsum.

Commercial gypsum deposits are found in many states with the leading producers being California, Iowa, Nevada, New York, Texas and Michigan and lesser amounts being produced in Colorado, and Oklahoma. Figure 5 shows the domestic locations of gypsum. The ore is mined underground and from open pits with the latter being the more general method because of lower costs. In 1958, 44 of the 62 mining operations were open pits, while three of the remainder were combinations of open pit and underground mines. In quarrying operations, stripping of the overburden is usually accomplished with drag lines or with tractors. Quarry drilling methods vary with local conditions; blasting is accomplished with low-speed, low density explosives. The fragmented ore is loaded with power shovels onto trucks or rail cars for transport to the processing facility. Generally, the primary crushing is done at the quarry site. Second-stage crushing is usually accomplished with gyratory units, and final crushing almost invariably by hammermills. The common unit for grinding raw gypsum is the air-swept roller mill. Ground gypsum is usually termed "land plaster" in the industry, because either sacked or in bulk, it is sold for agricultural purposes.

FIGURE 5

GYPSUM AND ASBESTOS OPERATIONS

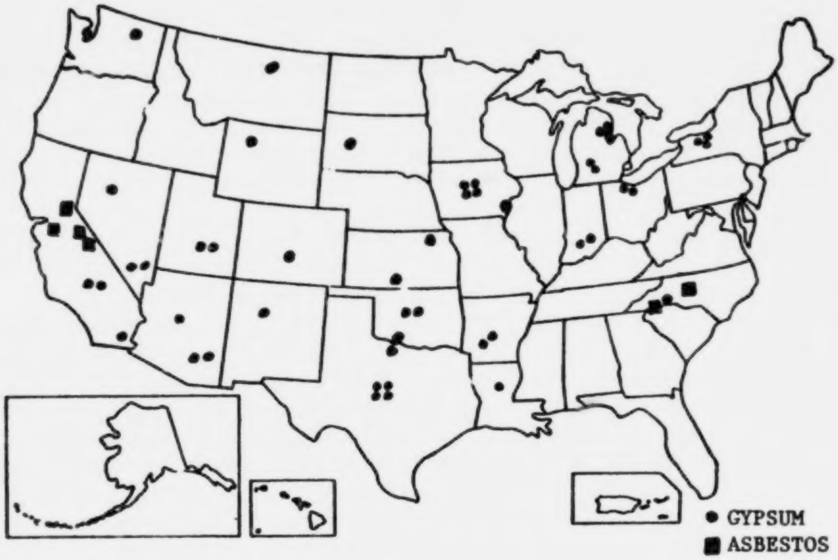
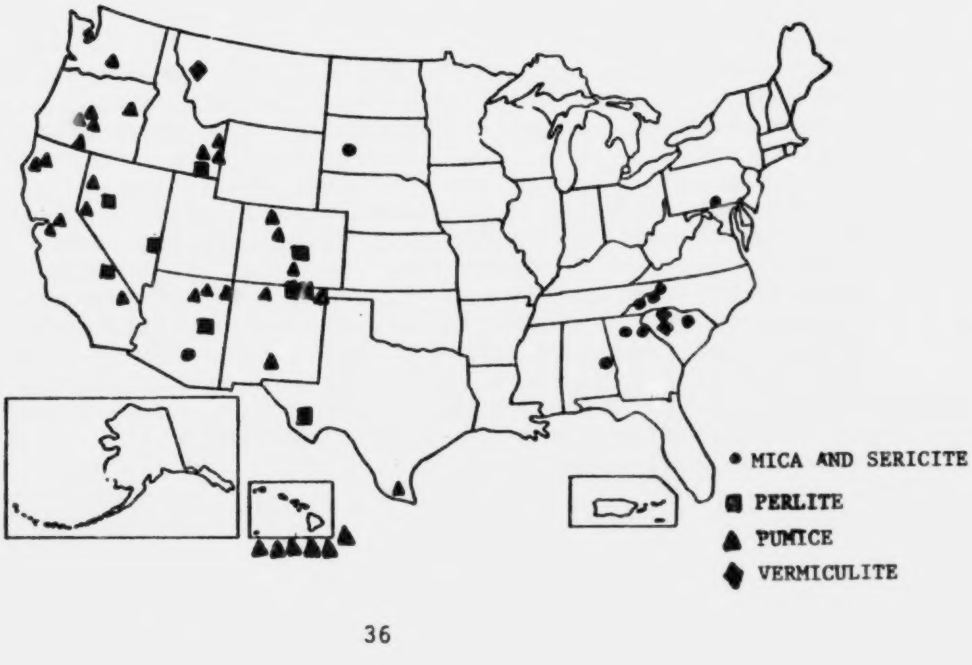

● GYPSUM
■ ASBESTOS

FIGURE 6

LIGHTWEIGHT AGGREGATES, MICA AND SERICITE OPERATIONS


● MICA AND SERICITE
■ PERLITE
▲ PUMICE
◆ VERMICULITE

In recent years, a trend has started towards the beneficiation of low-grade gypsum deposits where strategic location has made this economically feasiblé. The heavy-media method has been introduced in two Ohio facilities; screening and air separation have been employed for improving purity in a limited number of other operations. The tonnage of gypsum thus beneficiated is still a small part of the total output.

Most crushed gypsum is calcined to the hemi-hydrate stage by one of six different methods - kettles, rotary calciners, hollow-flight screw conveyers, impact grinding and calcining mills, autoclaves, and beehive ovens. The calcined gypsum is used for various types of plasters, board and block, preformed gypsum tile, partition tile, and roof plank. By far the largest use of calcined gypsum (stucco) is for the manufacture of board products. Gypsum board is a sandwich of gypsum between two layers of specially prepared paper. It is manufactured in large machines that mix stucco with water, foam and other ingredients and then pour this mixture upon a moving, continuous sheet of special heavy paper. Under "master rolls" the board is formed with the bottom paper receiving the wet slurry and another continually moving sheet of paper being placed on top. This sandwich is then compacted, cut, and dried.

ASPHALTIC MINERALS

The bitumens are defined as mixtures of hydrocarbons of natural or pyrogenous origin or combinations of both, frequently accompanied by their derivatives, which may be gaseous, liquid, semisolid or solid and which are completely soluble in carbon disulfide. Oil shale and like materials which are mined for their energy content are not covered by this subcategory.

The principal bituminous materials of commercial interest are:

(1) Native asphalts, solid or semisolid, associated with mineral matter such as Trinidad Lake asphalt. Selenitza, Boeton and Iraq asphalts.
(2) Native Asphaltites, such as gilsonite, grahamite and glance pitch, conspicuous by their hardness, brittleness and comparatively high softening point.
(3) Asphaltic bitumens obtained from non-asphaltic and asphaltic crude petroleum by distillation, blowing with air and the cracking of residual oils.
(4) Asphaltic pyrobitumens of which wurtzilite and elaterite are of chief interest industrially as they depolymerize

upon heating, becoming fusible and soluble in contrast to their original properties in these respects.

(5) Mineral waxes, such as ozokerite, characterized by their high crystallizable paraffine content.

There are several large deposits of bituminous sand, sandstone and limestone in various parts of the world but those of most commercial importance are located in the United States and Europe. Commercial deposits of bituminous limestone or sandstone in the United States are found in Texas, Oklahoma, Louisiana, Utah, Arkansas, California, and Alabama. The bitumen content in these deposits range from 4 to 14 percent. Some of the sandstone in California has a 15 percent content of bitumens, and a deposit in Oklahoma contains as high as 18 percent. The Uvalde County, Texas deposit is a conglomerate containing 10 to 20 percent of hard bitumen in limestone which must be mixed with a softer petroleum bitumen and an aggregate to produce a satisfactory paving mixture. Commercially, rock asphalt in this country is used almost exclusively for the paving of streets and highways. Rock asphalt is mined from open quarries by blasting and is reduced to fines in a series of crushers and then pulverized in roller mills to the size of sand grains varying from 200 mesh to 1/4 inch in size.

Gilsonite, originally known as uintaite is found in the Uintah basin in Utah and Colorado. Gilsonite is a hard, brittle, native bitumen with a variable but high softening point. It occurs in almost vertical fissures in rock varying in composition from sandstone to shale. The veins vary in width from 0.025 to 6.7 meters (1 in to 22 ft) and in length from a few kilometers to as much as 48 km (30 mi). The depth varies from a few meters to over 460 m (1500 ft). Mining difficulties, such as the creation of a very fine dust which in recent years resulted in two or three serious explosions, and the finding of new uses for gilsonite necessitated one company to supplement the conventional pick-and-shovel method by the hydraulic system. However, on some properties the mining is still done by hand labor, compressed air picks, etc.

Grahamite occurs in many localities in the United States and in various countries throughout the world but never in large amounts. The original deposit was discovered in West Virginia but has long been exhausted. Deposits in Oklahoma were exploited to a great extent for years but little is now mined in commercial quantities. The material differs from gilsonite and glance pitch having a much higher specific gravity and fixed carbon, and does not melt readily but intumesces on heating.

Glance pitch was first reported on the island of Barbados. The material is intermediate between gilsonite and grahamite. It has a specific gravity at 15.6°C of 1.09 to 1.15, a softening point (ring and ball) of 135° to 204°C and fixed carbon of 20 to 30 percent.

Wurtzilite, sometimes referred to as elaterite, is one of the asphaltic pyrobitumens and is distinguished by its hardness and infusibility. It is found in Uintah County, Utah, in vertical veins varying from 2.5 cm to 63.5 cm (1 in to 25 in) in width and from a few hundred meters to 4.8 km (3 miles) in length. It is used in the manufacture of paints, varnishes, as an extender in hard rubber compounds, and various weatherproofing and insulating compounds.

Ozokerite is a solid waxlike bitumen the principal supply of which is found in the Carpathian mountains in Galicia. A small amount of it is also found in Rumania, Russia and the state of Utah. The hydrocarbons of which it is composed are solids, resembling paraffin scale and resulted from evaporation and decomposition of paraffinaceous petroleum. It occurs in either a pure state or it may be mixed with sandstone or other mineral matter. The material is mined by hand and selected to separate any material containing extraneous matter. Ozokerite when refined by heating to about 182°C (360°F), treated with sulfuric acid, washed with alkali and filtered through fuller's earth is called "ceresine."

ASBESTOS (SIC 1499)

Asbestos is a broad term that is applied to a number of fibrous mineral silicates which are incombustible and which, by suitable mechanical processing, can be separated into fibers of various lengths and thicknesses. There are generally six varieties of asbestos that are recognized: the finely fibrous form of serpentine known as chrysotile and five members of the amphibole group, i.e., amosite, anthophyllite, crocidolite, tremolite, and actinolite. Chrysotile, which presently constitutes 93 percent of current world production, has the empirical formula $3MgO.2SiO_2.2H_2O$ and in the largest number of cases is derived from deposits whose host rocks are ultrabasic in composition. The bulk of chrysotile production comes from three principal areas: the Eastern Townships of Quebec in Canada, the Bajenova District in the Urals of USSR and from South Central Africa. The ore-body of greatest known content in the United States is found in the serpentine formation of Northern Vermont which is part of the Appalachian belt extending into Quebec. Figure 5 shows the domestic asbestos operations.

In North America the methods of asbestos mining are (1) open quarries, (2) open pits with glory holes, (3) shrinkage stoping, and (4) block caving; the tendency is toward more underground mining. In quarrying, the present trend is to work high benches up to 46 meters (150 feet) high and blast down 91,000 kkg (100,000 tons) or more of rock at a shot. An interesting feature of asbestos mining is that no wood may be used for any purpose unless it is protected, because it is impossible to separate wood fiber from asbestos in processing. Since the fiber recovery averages only 5 to 6 percent of the rock mined, very large tonnages must be handled. A capacity of 910 kkg/day (1,000 tons/day) is about the minimum for profitable operation.

Milling methods vary in detail, but they are nearly all identical in principle. The objects of processing are to recover as much of the original fiber as possible, free from dirt and adhering rock; to expand and fluff up the fiber; to handle the ore as gently as possible to minimize the reduction in fiber length by attrition; and to grade the fibers into different length groups best suited to use requirements. The general method in use is (1) coarse crushing in jaw or gyratory crushers, sometimes in two stages, to 3.8 to 5.1 cm (1-1/2 to 2 in); (2) drying to 1 percent or less moisture in rotary or vertical inclined-plane driers; (3) secondary crushing in short head cone crushers, gyratories, or hammer mills; (4) screening, usually in flat shaking or gyratory screens; (5) fine-crushing and fiberizing in stages, each stage followed by screening, during which air suction above the screens effects separation of the fiber from the rock; (6) collection of the fiber in cyclone separators, which also remove the dust; (7) grading of fibers in punched-plate trommel screens; (8) blending of products to make specification grades; and (9) bagging for shipment.

Fiberizing or opening up the bundles of fiber (step 5) is done in a special type of beater or impact mill designed to free the fiber from the rock and fluff up the fiber without reduction in fiber length. The screening operations are perhaps the most critical. The air in the exhaust hoods over each screen must be so adjusted that only the properly fiberized material will be lifted, leaving the rock and unopened fiber bundles for further fiberizing. The air system uses 20 to 25 percent of the total power consumed in a process facility.

WOLLASTONITE (SIC 1499)

Wollastonite is a naturally occurring, fibrous calcium silicate, $CaSiO_3$, which is found in metamorphic rocks in New

York and California, as well as several foreign locations. In the U.S. the mineral is mined only in New York. The material is useful as a ceramic raw material, as a filler for plastics and asphalt products, as a filler and an extender for paints, and in welding rod coatings. Due to its fibrous, non-combustible nature, wollastonite is also being considered as a possible substitute for asbestos in a number of product situations in which asbestos is objectionable. Wollastonite ore is mined by underground room and pillar methods and trucked to the processing facility. The ore is crushed in three stages, screened, dried, purified of garnet and other ferro-magnesium impurities via high-intensity magnetic separation and then ground to the desired product size.

LIGHT WEIGHT AGGREGATE MINERALS (SIC 1499)

PERLITE

Perlite is a natural glassy rhyolitic rock that is essentially a metastable amorphous aluminum silicate. It has an abundance of spherical or convolute cracks which cause it to break into small pearl-like masses usually less than a centimeter in diameter that were formed by the rapid cooling of acidic lavas. Since natural geological processes tend to work towards devitrification by progressive recrystallization and loss of water, most useful deposits of vitrified lava will be in recent lava flows of Tertiary or Quarternary age. Thus, most of the significant deposits of perlite in the United States are found in the Western states where active volcanism was recent enough that the perlite deposits are preserved. At the present time, the most important commercial deposit is in New Mexico.

Mining operations are open pit in locations chosen so that little overburden removal is required and where topographic factors are favorable for drainage and haulage of the crude ore. The ore is mined by loosening the perlite with a ripper and picked up with a pan scraper. In some cases fragmentation is accomplished by blasting followed by a power shovel loading.

Milling proceeds in a jaw crusher and secondary roll crusher with the normal screening operations. The sized ore, after removal of fines which constitute roughly 25 percent of the process facility feed, is dried in a rotary kiln to a residual moisture content below 1 percent and sent to storage for subsequent shipment to final processors.

The commercial uses of perlite depend upon the properties of expanded perlite. When rapidly heated to 850-1100°C the glassy nature of the natural material, coupled with the inclusion of considerable moisture, results in the rapid evolution of steam within the softened glass, causing an explosive expansion of the individual fragments and producing a frothy mass having 15 to 20 times the bulk of original material. The term perlite is applied to both the crude ore and the expanded product. Approximately 70 percent of consumption is as an aggregate for plaster, concrete and for prefabricated insulating board wherein the perlite inclusion results in an increase in the fireproof rating as well as a significant reduction in weight. The fact that perlite is relatively chemically inert, is relatively incompressible and has a large surface area to volume ratio, makes it useful as an important filter-aid material in the treatment of industrial water and in the beverage, food and pharmaceutical processing industry. Figure 6 locates the domestic perlite operations.

PUMICE

Pumice is a rhyolitic (the volcanic equivalent of a granite) glassy rock of igneous origin in which expanded gas bubbles have distended the magma to form a highly vesicular material. Pumicite has the same origin, chemical composition and glassy structure as pumice, but during formation the pumicite was blown into small particles. Hence the distinction is largely one of particle size in that pumicite has a particle size of less than 4 mm in diameter. Commercial usage has resulted in the generic term pumice being applied to all of the various rocks of volcanic ash origin. The chemical composition of pumice varies from 72 percent silica, 14 percent alumina and 4 percent combined calcium, magnesium and iron oxides for the most acidic types to approximately 45 percent silica, 16 percent alumina, and 30 percent combined calcium, magnesium, and iron oxides for the most basic types.

The distribution of pumice is world wide, but due to metamorphism only those areas of relatively recent volcanism yield pumice deposits of commercial importance. One great belt of significant deposits borders the Pacific Ocean; the other trends generally from the Mediterranean Sea to the Himalayas and thence to the East Indies where it intersects the first belt. The largest producers within the United States are found in California and Idaho.

Mining operations are currently by open pit methods with the overburden removed by standard earth moving equipment. Since most commercial deposits of pumice are unconsolidated, bulldozers, pan scrapers, draglines or power shovels can be used without prior fragmentation. When pumice is used for railroad ballast or road construction, the processing consists of simple crushing and screening. Preparation for aggregate usually follows a similar procedure but with somewhat more involved sizing to conform to rigorous specifications. Occasionally, the ore requires drying in rotary dryers either before or after crushing. Pumice prepared for abrasive use requires additional grinding followed by sizing via screening or air classification. The domestic pumice operations are located in Figure 6.

VERMICULITE

Vermiculite is the generic name applied to a family of hydrated-ferro-magnesium-aluminum silicates which, in the natural state readily split like mica into their laminaie which are soft, pliable, and inelastic. Vermiculite deposits are generally associated with ultrabasic igneous host rocks such as pyroxenite or serpentine from which the vermiculite seems to have been formed by hydrothermal activity. Biotite and phlogopite mica, which frequently occur with vermiculite, are considered to have a similar origin. When heated rapidly, to temperatures of the order of 1050-1100°C, vermiculite exfoliates by expanding at right angles to the cleavage into long wormlike pieces with an increase in bulk of from 8 to 12 times. The term vermiculite is applied both to the unexpanded mineral and to the commercial expanded product.

The bulk of domestically mined vermiculite comes either from the extensive deposit at Libby, Montana or from the group of deposits near Enoree, South Carolina. Mining operations are by open pit with removal of alluvial overburden accomplished by tractor-driven scrapers. The ore can be dug directly by power shovel or dragline excavator. Dikes or barren host rock require fragmentation by drilling and blasting prior to removal. Ore beneficiation is accomplished by wet processing operations using hammer mills, rod mills, rake classifiers, froth flotation, cyclones, and screens. Centrifuges and rotary driers are used to remove excess moisture following beneficiation. Exfoliation is carried out in vertical furnaces wherein the crude, sized vermiculite is top fed and maintained at temperatures from 900-1100°C for 4 to 8 seconds. The expanded product is removed by suction fans and passed through a classifier system to collect the product and to remove excessive fines. Figure 6 locates the domestic vermiculite operations.

MICA (SIC 1499)

Mica is a group name for a number of complex hydrous potassium aluminum silicate minerals differing in chemical compositions and in physical properties, but which are all characterized by excellent basal cleavage that facilitates splitting into thin, tough, flexible, elastic sheets. There are four principal types of mica named for the most common mineral in each type - muscovite, phlogopite, biotite and lepidolite with muscovite (potassium mica) being commercially the most important. Mica for commercial reasons is broken down into two broad classifications: sheet mica which consists of relatively flat sheets occurring in natural books or runs, and flake and scrap mica which includes all other forms.

Muscovite sheet mica is recovered only from pegmatite deposits where books or runs of mica occur sporadically as crystals which are approximately tabular hexagons ranging from a few centimeters to several meters in maximum dimension. Mica generally occurs as flakes of small particle size in many rocks. In addition, the mica content of some schists and kaolins is sufficiently high to justify recovery as scrap mica.

Domestic mica mining has been confined mainly to pegmatites in a few well-defined areas of the country. The largest area extends from central Virginia southward through western North and South Carolina and east-central Alabama. A second area lies discontinuously in the New England States, where New Hampshire, Connecticut, and Maine each possess mica bearing pegmatites. A third region comprises districts in the Black Hills of South Dakota and in Colorado, Idaho, and New Mexico. Additional sources of flake mica have been made available through the development of technology to extract small particle mica from schists and other host rocks. Deposits containing such mica are available throughout the U.S.

Sheet mica mines are usually small-scale operations. Open pit mining is used when economically feasible, but many mica bearing pegmatites are mined by underground methods. During mining, care must be taken to avoid drilling through good mica crystals. Only a few holes are shot at one time to avoid the destruction of the available mica sheet. Presently there is no significant quantity of sheet mica mined in the U.S. Larger scale quarrying methods are used to develop deposits for the extraction of small-particle-size mica and other co-product minerals.

Flake mica that is recovered from pegmatites, schist, or other rock is obtained by crushing and screening the host rock and additional beneficiation by flotation methods in order to remove mica and other co-product minerals. Then it is fed to an oil-fired rotary dryer. The dryer discharge goes to a screen from which the fines are either wasted or saved for further recovery.

Raw material for ground mica is obtained from sheet mica processing operations, from crushing and processing of schists, or as a co-product of kaolin or feldspar production. Buhr mills, rodmills, or high-speed hammer mills have been used for dry-grinding mica. An air separator returns any oversize material for additional grinding and discharges the fines to a screening operation. The various sized fractions are bagged for marketing. The ground mica yield from beneficiated scrap runs 95 to 96 percent.

"Micronized" mica is produced in a special type of dry-grinding machine, called a Micronizer. This ultrafine material is produced in a disintegrator that has no moving parts but uses jets of high-pressure superheated steam or air to reduce the mica to micron sizes. This type of mica is produced in particle size ranges of 10 to 20 microns and 5 to 10 microns.

Wet-ground mica is produced in chaser-type mills to preserve the sheen or luster of the mica. This consists of cylindrical steel tank that is lined with wooden blocks laid with the end grain up. Wooden rollers are generally used, which revolve at a slow rate of 15 to 30 revolutions per minute. Scrap goes to the mill, where water is added slowly to form a thick paste. When the bulk of the mica has been ground to the desired size, the charge is washed from the process facility into settling bins where gritty impurities sink. The ground mica overflows to a settling tank and is dewatered by centrifuging and steam drying. The final product is obtained by screening on enclosed multiple-deck vibrating screens, stored and then bagged for shipment. Figure 6 locates the domestic mica and sericite operations.

BARITE (SIC 1472 & 3295)

Barite, which is also called barytes, tiff, cawk or heavy spar, is almost pure barium sulfate and is the chief source of barium and its compounds. Barite deposits are widely distributed throughout the world, and can be classified into three main types: (a) vein and cavity filling deposits; (b) bedded deposits; and (c) residual deposits.

(a) Vein and cavity-filling deposits are those in which the barite and associated minerals occur along fault lines, bedding planes, breccia zones and solution channels. Barite deposits in the Mountain Pass district of California are of this variety.

(b) Bedded deposits are those in which the barite is restricted to certain beds or a sequence of beds in sedimentary rocks. The major commercial deposits in Arkansas, Missouri, California and Nevada are bedded deposits.

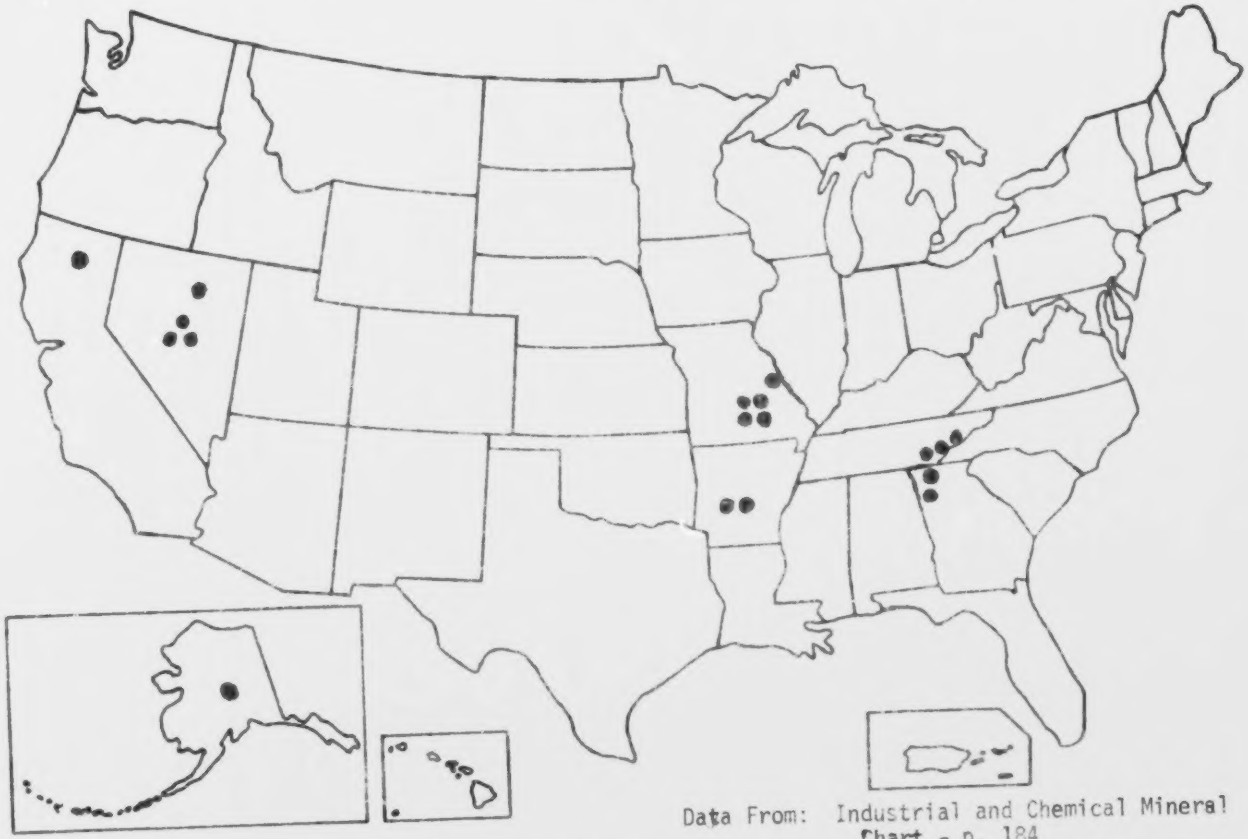
(c) Residual deposits occur in unconsolidated material that are formed by the weathering of pre-existing deposits. Such deposits are abundant in Missouri, Tennessee, Georgia, Virginia and Alabama where the barite is commonly found in a residuum of limestone and dolomites.

Mining methods used in the barite industry vary with the type and size of deposit and type of product made. Figure 7 displays the barite processing facilities in the United States. Residual barite in clay is dug with power shovels from open pits (Missouri, Tennessee, Georgia). Stripping is practiced when overburden is heavy, and the barite is then removed by dragline, tractors, scrapers, or power shovel. Overburden in Missouri is rarely over 0.6 or 0.9 meters (2 or 3 feet), but in Georgia it may range from 3 to 15 meters (10 to 50 feet). Hydraulic mining has been used at times in Georgia where overburden has been heavy, where troublesome limestone pinnacles have been encountered, or where tailing ponds have been reclaimed. Barite veins or beds are mined underground (Nevada, Tennessee, and Arkansas). Massive barite is blasted from open quarries with little or no subsequent sorting or beneficiation (Nevada).

Methods used in the beneficiation of barite depend both on the nature of the ore and on the type of product to be made. For the largest use, well-drilling mud, the only requirements are small particle size (325 mesh), chemical inactivity, and high specific gravity. White color is not essential, and purity is not important in many cases.

The essential features of the milling of residual barite in clay (Missouri, Georgia, and Tennessee, in part) include washing to remove the clay, hand picking to save lump barite, jigging to separate coarse concentrates, and tabling to recover fine concentrates. Further refinements may include magnetic separation to remove iron from concentrate fines and froth flotation to save the very finest barite. In Missouri, where the ore is so soft that crushing is unnecessary and individual deposits tend to be small, simple

FIGURE 7
BARITE PROCESSING PLANTS



Data From: Industrial and Chemical Mineral Chart - p. 184
The National Atlas of the USA
USGS - 1970

and inexpensive facilities that can be easily dismantled and moved are common. Missouri mills may consist essentially of only a double log washer, trommel, and jigs, but there are a few large mills. Hard, vein barite is usually pure enough to be shipped without beneficiation except hand sorting. In Georgia, the ore is hard and usually must be crushed to free the barite from the gangue; facilities tend to be large with several stages of crushing, screening, jigging and tabling.

The development of froth flotation methods have made deposits, such as those of Arkansas and Georgia, commercially valuable and have greatly increased recovery possibilities from other deposits. The Arkansas ore is particularly difficult to treat, since the barite is finely divided and so intimately mixed with the impurities that grinding to 325 mesh is necessary for complete liberation of the component minerals. The ground ore is then treated by froth flotation. Concentrates are filtered and dried in rotary kilns at temperatures high enough to destroy organic reagents that might interfere with use in drilling muds. In Georgia, flotation is being used to recover barite fines from washer tailings.

The methods used in grinding barite depend upon the nature of the product to be ground and upon the use for which the ground barite is to be sold. If white color is not important, as for well-drilling mud and off-color filler uses, iron grinding surfaces may be used. Where the color is naturally a good white and bleaching is not required, grinding is done with iron-free grinding surfaces, such as a dry pebble mill in closed circuit with an air separator.

The principal use of barite in the United States is as a weighting agent for drilling muds used in the oil industry. In addition, ground barite is used in the manufacture of glass and as a heavy filler in a number of products where additional weight is desirable.

FLUORSPAR (SIC 1473)

Fluorine is derived from the mineral fluorite, commonly known as fluorspar. Steadily increasing quantities are required in steel production where fluorite is useful as a slag thinner; in aluminum production, where cryolite is necessary to dissolve alumina for the electrolytic cells; and in ceramics, where fluorite is a flux and opacifier. Fluorine demand is strong for an important group of fluorocarbon chemicals which are formulated into refrigerants, plastics, solvents, aerosols, and many other industrial products.

In the Illinois-Kentucky district fluorspar occurs as veins in limestone, shale, and sandstone along faults ranging in thickness from a mere film to a width of more than 9 meters (30 feet) and in extensive flat-lying replacement-type deposits in limestone. Residual deposits, resulting from weathering of fluorite-bearing veins, are also fairly common in the district and often indicate the presence of vein deposits at greater depth.

In the Western States, fluorspar occurs under a wide variety of conditions such as fillings in fractures and shear zones forming more or less well-defined veins and as replacements in the country rock. Much occurs in igneous formations. Figure 8 depicts the locations of barite processing facilities in the United States.

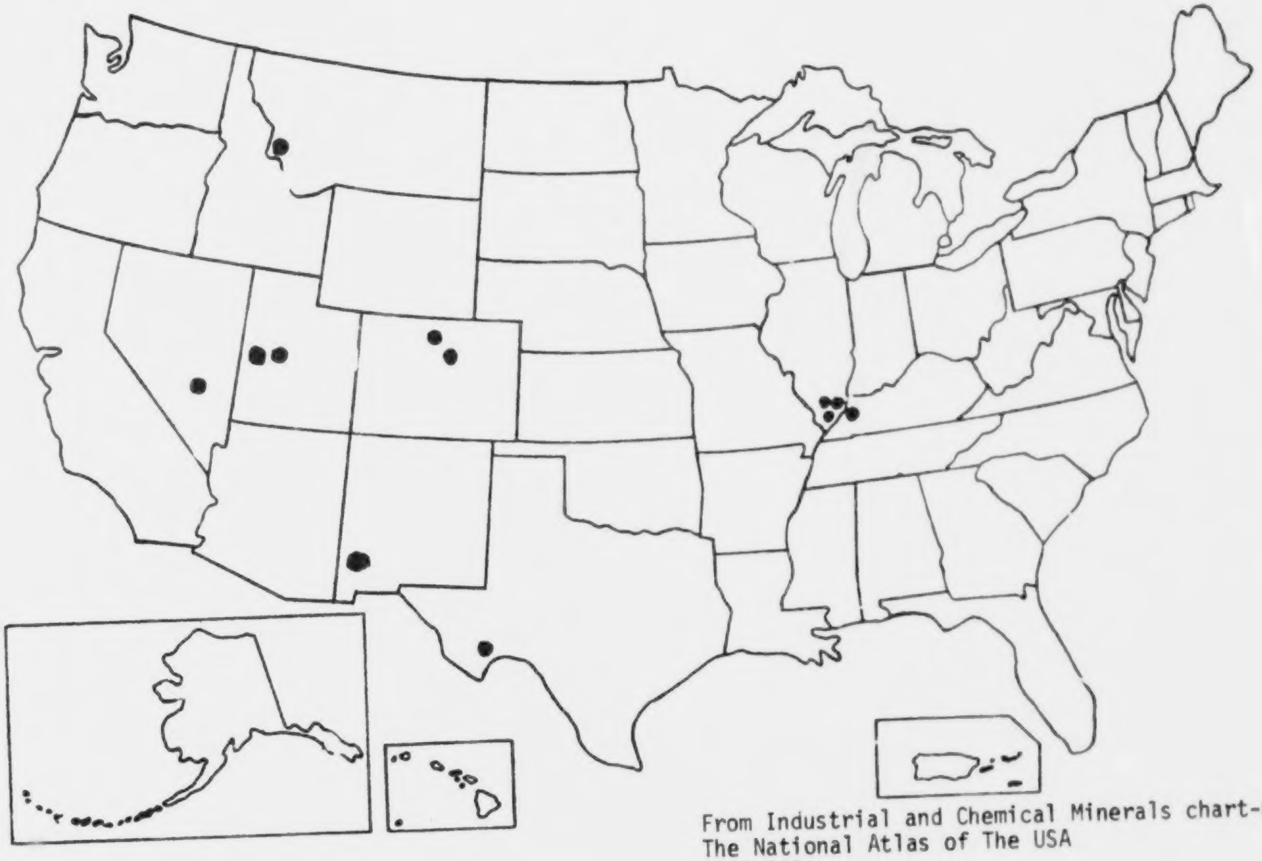
Mining is done by shafts, drifts, and open cuts with the mines ranging in size from small operations using mostly hand-operated equipment to large fully mechanized mines. Top slicing, cut-and-fill, shrinkage, and open stoping are among the mining methods commonly used. Bedded deposits are usually worked by a room-and-pillar system. Some of the large mines are extensively mechanized, using diesel-powered hauling and loading equipment.

The crude ore requires beneficiation to yield a finished product. Processing techniques range from rather simple methods, such as hand sorting, washing, screening and gravity separation by jigs and tables, to sink-float and froth-flotation processes. The flotation process permits recovery of the lead, zinc, and barite minerals often associated with the fluorspar ores. Flotation is used where a product of fine particle size is desired, such as ceramic- and acid-grade fluorspar. The heavy-medium or sink-float process is usually employed where a coarse product, such as metallurgical-grade gravel is desired.

SALINES FROM BRINE LAKES (SIC 1474)

A number of the potash, soda and borate minerals are produced from the brines of Western lakes that have evaporated over long periods of time to a high concentration of minerals. The significant commercial exploitation of these lake brines is at Searles Lake in California and the Great Salt Lake in Utah. Two facilities are operated at Searles Lake that employ a complex series of evaporation steps to recover minerals and, in some instances, produce other derived products such as bromine and boric acid. The process sequence is called the "Trona Process", which should not be confused with trona ore (natural sodium carbonate) mining that takes place in Sweetwater County, Wyoming. One

FIGURE 8
FLUORSPAR PROCESSING PLANTS



From Industrial and Chemical Minerals chart-pg.184
The National Atlas of The USA
USGS-1970

facility utilizes an evaporative process at the Great Salt Lake to produce sodium sulfate, salt, potassium sulfate, and bittern liquors. Figure 9 shows the potash deposits in the United States including brine recovery. Figure 10 shows all of the borate deposits. Figure 11 shows the calcium and magnesium brine locations.

BORATES (SIC 1474)

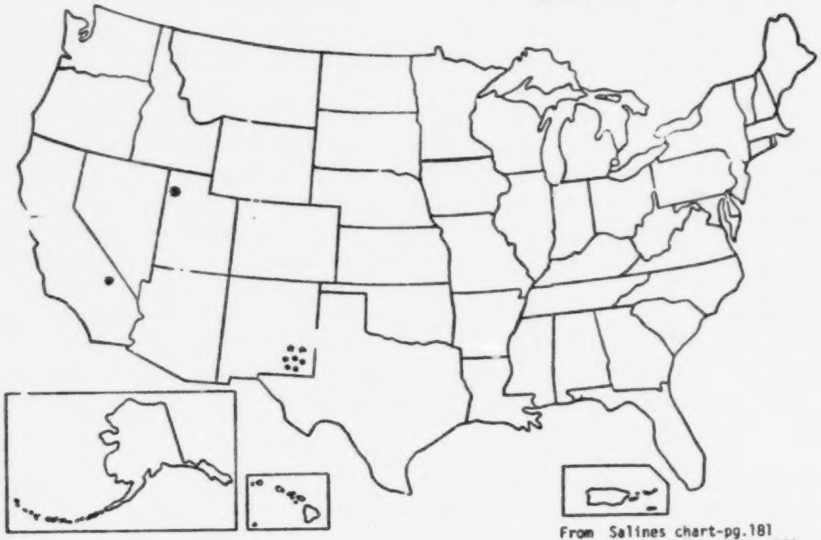
While boron is not an extremely rare element, few commercially attractive deposits of boron minerals are known. It is estimated that about half of the commercial world boron reserves, estimated at about 65 million kkg (72 million tons), are in southern California as bedded deposits of borax (sodium borate) and colemanite (calcium borate), or occur as solutions of boron minerals in Searles Lake brines. Figure 10 shows the location of the United States operations. The United States is the largest producer of boron, supplying 71 percent of the world demand in 1968, and also the largest consumer, requiring about 36 percent of the world output.

Many minerals contain boron, but only a few are commercially valuable as a source of boron. The principal boron minerals are borax (tincal), $Na_2B_4O_7 \cdot 10H_2O$; kernite (rasorite), $Na_2B_4O_7 \cdot 4H_2O$; colemanite (borocalcite), $Ca_2B_6O_{11} \cdot 5H_2O$; ulexite (boronatrocalcite), $CaNaB_5O_9 \cdot 8H_2O$; priceite (pandermite), $5CaO \cdot 6B_2O_3 \cdot 9H_2O$; boracite (stassfurtite), $Mg_7Cl_2B_{16}O_{30}$; and sassolite (natural boric acid), H_3BO_3. The sodium borate minerals borax and kernite (rasorite) constitute the bulk of production in the United States. A small quantity of colemanite and ulexite is also mined.

The borate deposit in the Kramer district of California is a large, irregular mass of bedded crystalline sodium borate ranging from 24 to about 305 meters (80 to 1,000 feet) in thickness. Borax, locally called tincal, and kernite are the principal minerals. Shale beds containing colemanite and ulexite lie directly over and under the sodium borate body.

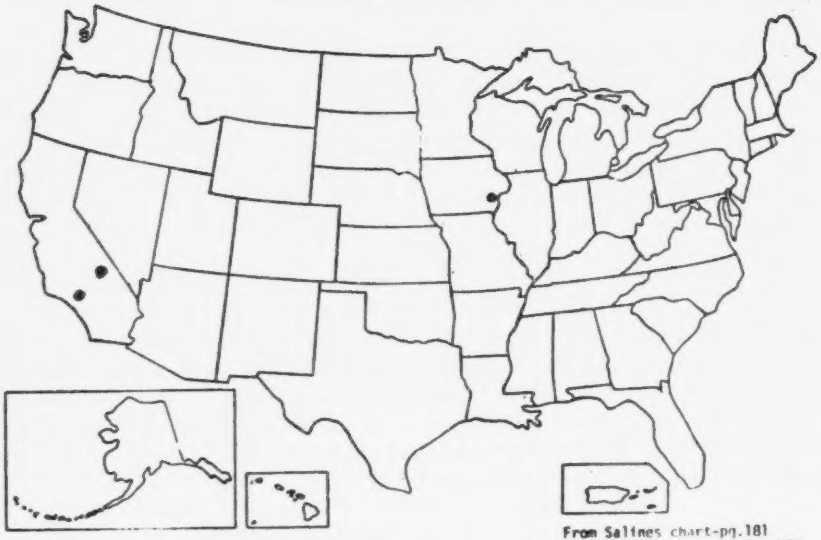
One company mines the ore by open-pit methods. It is blended and crushed to produce a minus 1.9 centimeters (3/4 inch) feed of nearly constant boric oxide (B_2O_3) content. Weak borax liquor from the refinery is mixed with the crushed ore and heated nearly to boiling point in steam-jacketed tanks to dissolve the borax. The concentrated borax liquor is processed in a series of thickeners, filtered and pumped to vacuum crystallizers. One of the crystallizers produces borax pentahydrate, and the other produces borax decahydrate.

FIGURE 9
POTASH DEPOSITS


• -Mines
● -Wells
● -Surface brines

From Salines chart-pg.181
The National Atlas of The USA
USGS-1970

FIGURE 10
BORATE OPERATIONS



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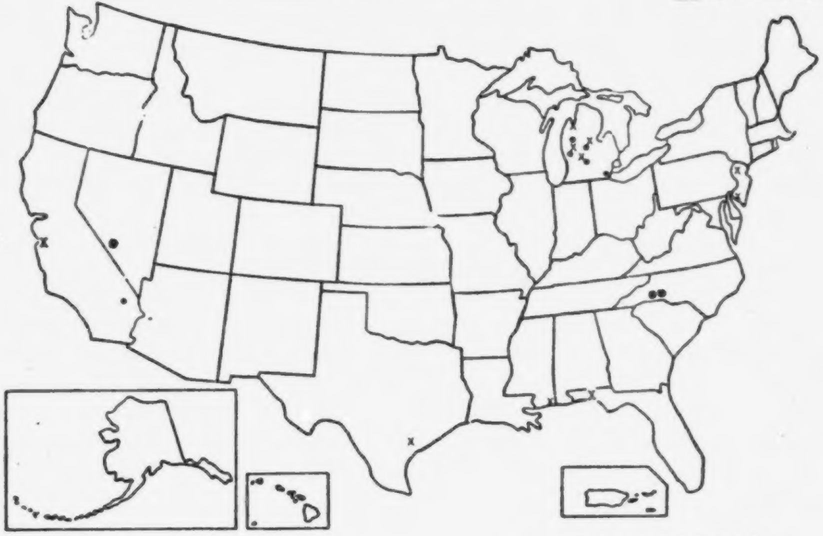
USGS-1970

FIGURE 11
LITHIUM, CALCIUM AND MAGNESIUM


● Lithium
• Calcium compounds(Brine)
x Magnesium comp.(Brine)

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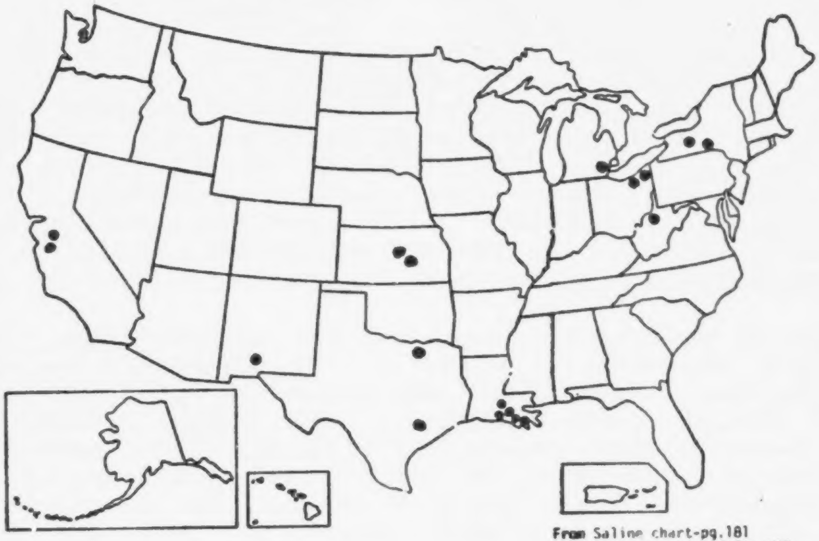
The National Atlas of The USA
USGS-1970

FIGURE 12
ROCK SALT MINES AND WELLS



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The National Atlas of The USA
USGS-1970

Sodium borates are also extracted from Searles Lake brines by a company whose primary products are soda ash, salt cake, and potash. Searles Lake is a dry lake covering about 88 square km (34 square miles) in San Bernardino County, California. Brines pumped from beneath the crystallized surface of the lake are processed by carbonation, evaporation, and crystallization procedures, producing an array of products including boron compounds.

Ferroboron is a boron iron alloy containing 0.2 to 24 percent boron, and is marketed in various grain sizes. Boric oxide is a hard, brittle, colorless solid resembling glass. It is marketed in powder or granular forms.

Borax ($Na_2B_4O_7 \cdot 10H_2O$), the most commonly known boron compound, is normally marketed with 99.5 percent purity. It is also available in technical, U.S.P., and special-quality grades. In addition to the decahydrate, the pentahydrate ($Na_2B_4O_7 \cdot 5H_2O$) and anhydrous forms are sold. The various grades are available in crystalline, granular, or powder forms. Boric acid (H_3BO_3) is a colorless, odorless, crystalline solid sold in technical, U.S.P., and special quality grades. It is available in crystalline, granular, or powder forms.

Boron compounds are mined in a remote desert area where tailings and waste dumps do not encroach on residential, industrial, or farm land. Atmospheric pollution is not a problem, although some processing odors and dust are produced.

POTASH (SIC 1474)

The term "potash" was derived from the residues, pot ashes, originally obtained by evaporating in iron pots solutions leached from wood ashes. The present worldwide meaning of potash is twofold. When used as a noun, it represents K_2O equivalent, and when used as an adjective, it means potassium compounds or potassium-bearing materials. Sylvinite, the major ore for producing potash, comes from underground mines in New Mexico, Canada and Europe, and is a mineralogical mixture of sylvite (KCl) and halite (NaCl).

Domestic sources for potassium are of two types: brines and bedded deposits. Currently 84 percent of domestic production comes from the bedded deposits in southeastern New Mexico near Carlsbad. The higher grade (20 to 25 percent K_2O) commercial ore in this area is nearing depletion and most of the seven producing firms are estimated to have only a 6- to 10-year supply. U. S. production reached a peak output in 1966 and has since declined. Figure 9 shows the locations of the domestic deposits.

In the conventional shaft-type mining operations, large continuous mining machines are used in both the New Mexico and Canadian mines. Room-and-pillar mining methods are used in New Mexico with a first-run extraction of about 65 percent while in the deeper Canadian mines the first-run extraction is in the order of 35 percent. On the second pass in the New Mexico mines at least 55 percent of the remining potash is recovered by "pillar robbing" for a total extraction of about 83 percent of ore body. As much as 90 percent recovery has been claimed for some operations. Pillar robbing is not practiced in Canada and because of the greater mine depth it is not likely to be with present technology.

Two basic methods of ore treatment, flotation and fractional crystallization, are used both in the Carlsbad area and in Canada to recover sylvite from the ore. In general, the crushed ore is mixed with a brine saturated with both sodium and potassium chlorides and deslimed to remove most of the clay impurities. The pulp is conditioned with an amine flotation reagent and sent to flotation cells where the sylvite is separated from the halite, the principal impurity. The halite fraction is repulped and pumped to the tailings areas; the sylvite concentrate is dried, sized, and shipped or sent to storage.

Fractional crystallization is based on the specific difference in the solubility-temperature relationships of sodium chloride and potassium chloride in saturated solution. Crushed ore is mixed with hot, saturated sodium chloride brine, which selectively dissolves the potassium chloride. The brine is then cooled causing the potassium chloride to crystallize as a 99 percent pure product.

Langbeinite is separated from halite, its principal impurity, by the selective solution of the halite. The flotation process is also used to separate langbeinite from sylvite.

Potassium compounds are recovered from brines, including brines from solution mining, by evaporation and fractional crystallization. The sodium salts in Searles Lake brines are separated in triple-effect evaporators, leaving a hot liquor rich in potash and borax. Rapid cooling of the sodium-free solution under vacuum causes the potassium salts to crystallize. The crystals of potassium salts are then removed by settling and centrifuging.

About 84 percent of the domestic potash is produced in a 142 square km (55-square mile) area 24 km (15 miles) east of Carlsbad, New Mexico. There are eight refineries in this district, each requiring large tailing disposal areas consisting largely of sodium chloride salt; consequently, areas covered with this waste are incapable of supporting any plant growth. The operation near Moab, Utah, is similarly located, but extreme care is exercised to prevent pollution of the nearby Colorado River.

The brine operation in Utah requires large evaporating pans covering many acres of the land surface. The process involved here involves evaporation of Great Salt Lake waters first to recover common salt (NaCl) and then potassium sulfate. Residual brines, containing mostly magnesium and lithium salts are returned to the lake.

TRONA (SIC 1474)

Trona ($Na_2CO_3NaHCO_3 \bullet 2H_2O$) is the most common sodium carbonate mineral found in nature. It crystallizes when carbon dioxide gas is bubbled through solutions having a concentration of sodium carbonate greater than 9 percent. Carbonation of less concentrated solutions precipitates sodium bicarbonate. The largest known deposit of relatively pure trona in the United States was discovered in southwest Wyoming in 1938 while drilling for oil near Green River. The deposit is relatively free of chlorides and sulfates and contains 5 to 10 percent insoluble matter and constitutes the only mineable quantity of this material. It is also the world's largest natural source of sodium carbonate (soda ash).

Trona is a sedimentary deposit precipitated in the bottom of the ancient Eocene Lake Gosiute. Subsequent deposits of oil shale, siltstone and sandstone covered the trona, and the beds that are mined 240 to 460 meters (800 to 1500 feet) below the surface. Approximately 25 different trona-bearing beds lie buried at depths of 130 to 1100 meters (440 to 3500 feet).

Trona ore mining is carried out near Green River, Wyoming by four corporations. Only three have soda ash refining facilities on site at the present time. The increasing industrial use of soda ash, together with the phasing out of obsolete and controversial synthetic soda ash facilities in the East has caused a great spurt of growth in the trona ore industry from the early 1960's. The mineable resources of trona in this area have been estimated to be 45 billion kkg (50 billion short tons).

SODIUM SULFATE

Natural sodium sulfate is derived from the brines of Searles Lake in California, certain underground brines in Texas, and dry lake brines in Wyoming. Sodium sulfate is also derived as a by-product from rayon production, which requires that caustic solutions used in processing cellulose fiber be neutralized with sulfuric acid. Other sources of by-product sodium sulfate include the chemical processes that produce hydrochloric acid, cellophane, boric acid, lithium carbonate, phenol, and formic acid.

The natural sodium sulfate is produced by six facilities in California, Utah, and Texas. Three facilities in California produce 74 percent of the natural product.

ROCK SALT (SIC 1476)

Sodium chloride, or salt, is the chief source of all forms of sodium. Salt is produced on a large scale from bedded and dome-type underground deposits and by evaporating lake and sea brines. Increasing quantities of two commercially important sodium compounds, sodium carbonate (soda ash) and sodium sulfate (salt cake), are produced from natural deposits of these compounds, although salt is still the main source of both.

Bedded salt deposits are formed when a body of sea water becomes isolated from the circulating ocean currents by a reef, sandbar, or other means, and under suitably dry and warm climatic conditions evaporation proceeds until the salts are partially or entirely deposited. With continuous or periodic influx of sea water to replace evaporation, large deposits of salt have been built up in some instances to several thousand meters in thickness. Deposits of this type have also been called lagoonal. During the Permian geologic age two famous salt deposits of the lagoonal type were laid down, one in northern Germany and the other in eastern New Mexico. A second large bedded deposit in the United States is the Silurian salt deposit, which underlies Michigan, New York, Pennsylvania, Ohio, and West Virginia. It was formed in much the same manner as the Permian beds by the evaporation of a large inland sea which became separated from the ocean and gradually evaporated.

Playa deposits were formed by the leaching of surrounding sediments with water, which subsequently drained into a landlocked area and evaporated, leaving the salts. The composition of the brines and salt beds of these deposits generally does not resemble that of sea water; playa deposits of California and Nevada also contain sodium carbonate, sodium sulfate, potash and boron.

Salt domes are large vertical structures of salt, resulting from the deformation of deeply buried salt beds by great pressure. The plastic nature of halite under high temperature and pressure and its low density, compared with that of the surrounding rock, permited deeply buried sedimentary deposits to be forced upward through zones of weakness in the overlying rocks, forming vertical columns or domes of salt extending several thousand meters in height and cross section. If the bedded deposit at the base of the dome is sufficiently large, the salt columns may rise to the surface. There are reportedly 300 salt domes in the Gulf coast area from Alabama to Mexico.

Rock salt is mined on a large scale in Michigan, Texas, New York, Louisiana, Ohio, Utah, New Mexico, and Kansas, with room-and-pillar the principal mining method. Rooms vary in size depending on the thickness of the seam and other factors. In one mine an undercutter cuts a slot 3 meters (10 feet) deep at the base of the wall, which is then drilled and blasted. About 0.2 kg of dynamite per kkg of salt is required. The broken salt is transported by various mechanical means such as loaders, trucks, and belt conveyors to the underground crushing area. The salt may be processed through a number of crushing and screening stages prior to being hoisted to the surface where the final sizing and preparation for shipment or further use is carried out.

About 57 percent of the U.S. salt output is produced by introducing water into a cavity in the salt deposits and removing the brine. This procedure is relatively simple and has particular advantage when the salt is to be used as a brine as, for example, in chemical uses such as soda ash and caustic manufacture. Holes are drilled through the overburden into the deposit and cased with iron pipe. Water is introduced into the deposit through a smaller pipe inside the casing. A nearly saturated brine is formed in the cavity at the foot of the pipe. This brine is pumped or airlifted through the annular space between the pipes. Figure 12 shows the locations of current rock salt operations in the United States.

PHOSPHATE ROCK (SIC 1475)

The term "phosphate rock" includes phosphatized limestones, sandstones, shales, and igneous rocks which do not have a definite chemical composition. The major phosphorus minerals of most phosphate rock are in the apatite group and can be represented by the generalized formula $Ca_5(PO_4)_3$ -

(F, Cl, OH). The (F, Cl, OH) radical may be all fluorine, chlorine, or hydroxyl ions or any combination thereof. The (PO_4) radical can be partly replaced by small quantities of VO_4, AsO_4, SiO_4, SO_4, and CO_3. Also, small quantities of calcium may be replaced by elements such as magnesium, manganese, strontium, lead, sodium, uranium, cerium, and yttrium. The major impurities include iron as limonite, clay, aluminum, fluorine, and silica as quartz sand. Phosphate rock occurs as nodular phosphates, residual weathered phosphatic limestones, vein phosphates, and consolidated and unconsolidated phosphatic sediments. The best known of the apatite minerals, fluorapatite is widely distributed. Relatively small deposits of fluorapatite occur in many parts of the world. The domestic deposits that are currently being exploited are indicated in Figure 13.

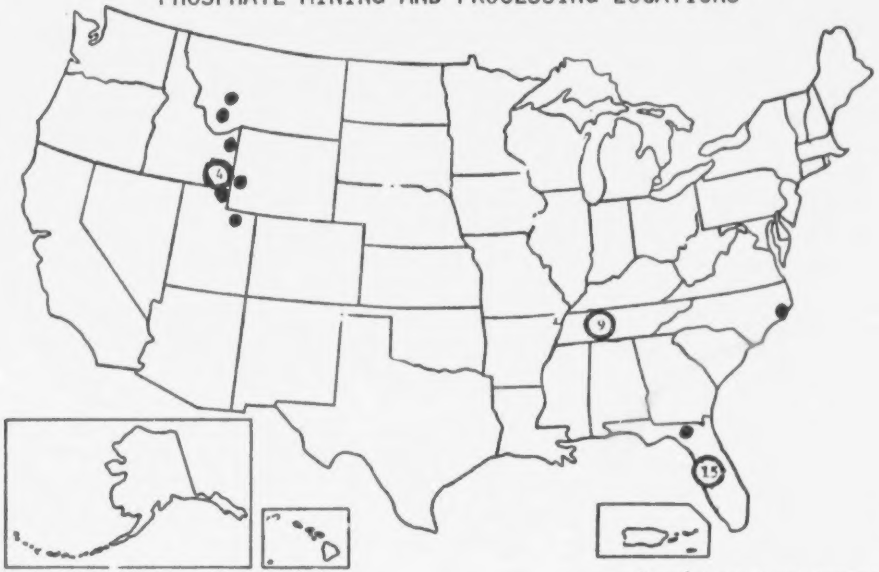
Phosphate ore is mined by open pit methods in all four producing areas: Florida, North Carolina, Tennessee, and the Western States. In the Florida land-pebble deposits, the overburden is stripped and the ore mined by large electric dragline excavators equipped with buckets, with capacities up to 123 cubic meters (49 cubic yards). The ore is slurried and pumped to the washing facility, in some instances several miles from the mine. In the Tennessee field and the open pit mines in the western field, the ore is mined by smaller dragline excavators, scrapers or shovels and trucked to the facilities. In North Carolina a 180 cubic meter (72 cubic yard) dragline is used for stripping, and the ore is then hydraulically transported to the washer.

Washing is accomplished by sizing screens, log washers, various types of classifiers, and mills to disintegrate the large clay balls. The fine slime, usually minus 150 mesh, is discarded. In the Florida land-pebble field, the plus 14 mesh material is dried amd marketed as high-grade rock or sometimes blended with the fine granular material (minus 14, plus 150 mesh) that has been treated in flotation cells, spirals, cones or tables. Losses in washing and flotation operations, which range from 40 percent of the phosphorus in the Florida operations to more than 50 percent in some Tennessee areas, occur in the form of slimes containing 4 to 6 percent solids. These slimes are discharged into settling ponds, where initial settling occurs, and substantial quantities of relatively clear water is returned to the mining and washing operations.

Some of the western field phosphate rock production is of suitable grade as it comes from the mine. Siliceous phosphate ore and mixtures of phosphate rock and clay minerals are amenable to benefication, and in 1968 three

FIGURE 13

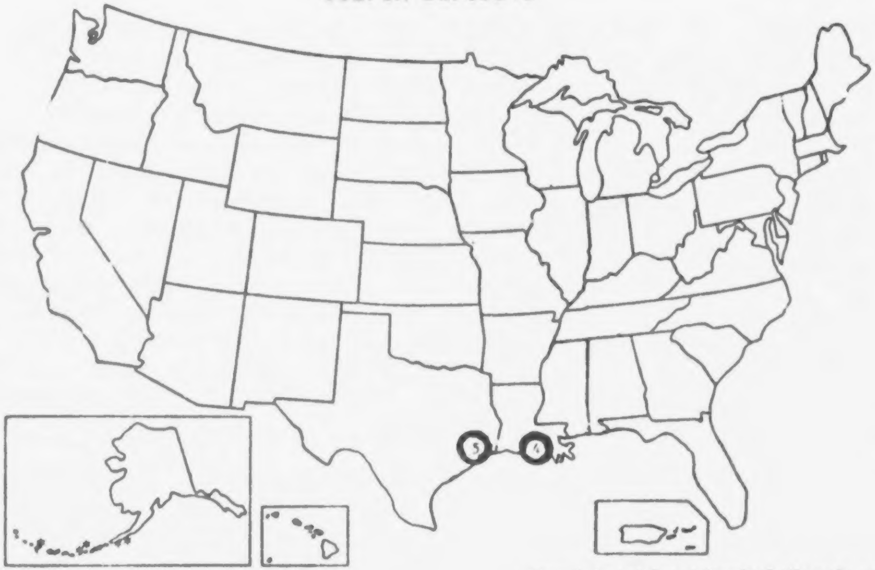
PHOSPHATE MINING AND PROCESSING LOCATIONS



From Industrial and Chemical Minerals chart-pg.184.
The National Atlas of The USA
USGS-1970

FIGURE 14

SULFUR DEPOSITS



From Industrial and Chemical Minerals chart-pg.184
The National Atlas of The USA
USGS-1970

companies in the western field were beneficiating part of their production. Two flotation facilities and several washing facilities were in operation in 1968.

Several environmental problems are associated with the phosphorus and phosphate industry. In the southeastern states mining and processing of phosphate rock is located close to developed and expanding urban areas. In the Florida land-pebble district the phosphate matrix (ore) underlies 1.2 to 18 meters (4 to 60 feet) of overburden consisting mostly of sand and clay requiring the use of large draglines to remove the overburden. The major mining companies, together and individually, have embarked upon a continuing program of reclamation of mined-out areas and are planning mining operations to provide easier and more economical methods of reclamation. Many thousands of acres of land have been reclaimed since the program started.

The Florida phosphate rock washing operations, because of the nature of the material, produces large quantities of a slurry of very fine clay and phosphate minerals called slimes. This is a waste product and must be contained in slime ponds that cover large areas since many years of settling are required before these pond areas can be reclaimed. Much research effort has been expended by both government and industry to solve this problem which is not only an environmental one but also one of conservation since about 33 percent of the phosphorus values are wasted. Some progress has been made and old slime ponds are now being reclaimed for recreational, agricultural, and other uses. The greatest problems of this nature exist in central Florida but similar situations prevail in northern Florida and Tennessee.

SULFUR (SIC 1477)

Elemental sulfur is found in many localities generally in solfataras and gypsum-type deposits. By far, most of the world's supply of sulfur comes from the gypsum-type deposits where it occurs as either crystalline or amorphous sulfur in sedimentary rocks in close association with gypsum and limestone. The origin of such deposits has been variously attributed to geochemical processes involving the reduction of calcium sulfate by carbon or methane followed by oxygenation of the resulting hydrogen sulfide; or to biochemical processes involving the reduction of sulfate to sulfide by various microorganisms.

The major domestic sources of sulfur are associated with the Gulf Coast salt domes which characteristically are circular or oval in cross-section with the sulfur-bearing cap rock occurring at depths of less than 900 meters (3000 feet). The diameter of the domes may vary from 0.8 to 8 km (0.5 to 5 miles) with a dry, compact, coarsely crystalline salt column below the cap rock. Most of the elemental sulfur is found in the limestone or carbonate zone of the cap rock with a horizon which may vary from nearly zero to several hundred meters in thickness having sulfur content which may range from traces to more than 40 percent.

The sulfur formations in West Texas are in porous zones of gently dipping dolomitic limestone, silty shale, anhydride and gypsum. The sulfur deposits are low grade and the layers that contain sulfur are thin. Depths of the sulfur deposits range from 200 to 460 meters (700 to 1,500 feet). Surface exposures of sulfur in porous gypsum and anhydrite are distributed over a rectangular area about 64 km long and 48 km wide (40 miles long and 30 miles wide) in both Culberson and Reeves counties.

Mining of sulfur is accomplished by the Frasch or hot water process. In the Frasch process, the sulfur is melted underground by pumping super heated water in to the formation. The molten sulfur is then raised to the surface through the drill pipe and stored in liquid form in steam-heated tanks. In most installations, the liquid sulfur is pumped directly into heated and insulated ships or barges that can transport the sulfur in liquid form. Approximately 15 percent of the total sulfur produced in the U.S. is metered and pumped to storage vats for cooling and solidifying before it is sold in dry form.

Sulfur has widespread use in the manufacturing of fertilizers, paper, rubber, petroleum products, chemicals, plastics, steel, paints and other commodities, with the fertilizer industry consuming approximately 50 percent of the total U.S. sulfur production. The locations of the United States sulfur deposits are shown in Figure 14.

MINERAL PIGMENTS

The mineral pigments consist of three general groups:

(1) Those consisting mostly of iron oxides such as hematite and limonite.
(2) Those containing large amounts of clay or noncoloring matter, such as ocher, sienna, umber and colored shales.
(3) Those whose color is not due to iron oxide such as Vandyke brown, graphite and terre-verte.

Since the coloring power of the natural yellow, red, and brown mineral pigments is due principally to the content and condition of iron oxide, the occurrence of mineral pigments in many instances is closely allied to that of the iron ores. Pigment materials and iron ores often are mined in the same localities, and iron ores are used at times for mineral pigments of the red and brown varieties. The iron oxides are almost universally distributed.

Replacement or precipitation deposits are the principal sources of limonite and ocherous minerals. They have been deposited in cavities by ground waters charged with iron salts removed from the weathering of impure limestone, sandstones, and shales, especially when pyrite was an accessory mineral. The most important deposits are found usually in the fractured and faulted zones of rocks of all ages, including the Cambrian quartzites of Georgia, the Paleozoic limestones and quartzites of Pennsylvania, and the unconsolidated Tertiary clays, sands, manganese ores, and lignites of Vermont.

In Virginia, deposits of residual limonite occur in two belts, one extending along the west slope of the Blue Ridge from Warren to Roanoke County and the other along the east side of the New River-Cripple Creek district, Pulaski County, and near the boundary of Wythe and Carroll Counties. The latter deposits are associated with Cambrian quartzites. The deposits in Pulaski County have produced ochers of high iron content somewhat similar in analyses and properties to the Georgia ocher.

The chief production of earth pigments in the United States in recent years has come from Pennsylvania, Virginia, Illinois, Minnesota, Georgia, California, and New York. In Pennsylvania, ocher is mined both by opencut methods and shafts, and in Georgia by opencut methods. In most deposits the pockety character of the ore and the uncertain market for the product do not justify elaborate equipment.

The soft, claylike pigments are treated by comparatively simple washing processes, followed by dehydration and pulverization. Log washers and blungers are used for dispersion; trough, cone, and bowl classifiers separate the sand from the fine suspension. A portion of the water is removed in settling tanks and the remainder is extracted by filter presses and rotary driers. Hammer type pulverizers reduce the pigment to powder for packing and shipment and a final air separation may be interposed for the better grades.

LITHIUM MINERALS (SIC 1479)

Spodumene, petalite, lepidolite, and amblygonite are the minerals from which lithium is derived. Brines are another source of lithium. Domestic spodumene is recovered by mechanical mining and milling processes, and either an acid or an alkali method is used to extract lithium compounds from the spodumene ore.

Lithium minerals have been mined from pegmatite depostis by open pit and underground methods. Other minerals such as beryl, columbite, feldspar, mica, pollucite, quartz, and tantalite are often extracted and recovered as coproducts in the mining process.

In North Carolina spodumene is recovered from the pegmatite ore by crushing, screening, grinding, and flotation, and lithium compounds are recovered from spodumene concentrates by an acid or an alkali treatment. In the method employing acid, spodumene is changed from the alpha form to the beta form by calcining at 982°C (1,800°F). Next it is added to sulfuric acid and the mixture is heated until lithium sulfate is formed. The sulfate is then leached from the mass, neutralized with limestone, and filtered. Soda ash is added to the sulfate solution in order to precipitate lithium carbonate from which most of the other compound forms are prepared. In the alkali treatment, spodumene is stage-calcined with powdered limestone and hydrolyzed with steam to produce a water-soluble lithium oxide. This can be easily recovered and converted to the desired lithium compound.

Certain natural brines are also a source of lithium. At Searles Lake, California, brine (0.033 percent lithium chloride) is first concentrated in evaporators causing several salts to precipitate, including dilithium sodium phosphate, sodium chloride, and a mixture of other sodium salts. Through a combined leach-flotation process the lithium compound is recovered as crystals and then fed to a chemical facility to be converted to lithium carbonate. The brines at Silver Peak, Nevada (0.244 percent LiCl) are concentrated to a LiCl content of 6 percent by solar evaporation. This concentrate is then pumped to a nearby mill where a soda ash process changes the chloride to solid lithium carbonate. Lithium metal is produced by the electrolysis of lithium chloride. Figure 11 shows the domestic lithium deposits.

CLAYS

Clays and other ceramic and refractory materials differ primarily because of varying crystal structure, presence of significant non-clay materials, variable ratios of alumina and silica, and variable degrees of hydration and hardness. This industry, together with ore mining and coal mining, differs significantly from the process industries for which effluent limitation guidelines have previously been developed. The industry is characterized by an extremely variable raw waste load, depending almost entirely upon the characteristics of the natural deposit. The prevalent pollutant problem is suspended solids, which vary significantly in quantity and treatability.

For the purpose of this section we will define clay as a naturally occurring, fine-grained material whose composition is based on one or more clay minerals and contains impurities. The basic formula is $Al_2O_3SiO_3.{}_xH_2O$. Important impurities are iron, calcium, magnesium, potassium, and sodium which can either be located interstitially in the hydrous aluminum silicate matrix or can replace elements in the clay minerals. As it may be imagined there is a infinite mixture of clay minerals and impurities, and a solution for nomenclature would seem insurmountable. The problem is solved somewhat haphazardly by classifying a clay according to its principal clay mineral (e.g. kaolin-kaolinite), by its commercial use (e.g. fire clay and fuller's earth) or by its properties (e.g. plastic clay). Much clay, however, is called just common clay. Some of the principal clay minerals are kaolinite, montmorillonite, attapulgite, and illite.

Kaolinite consists of alternating layers of silica tetrahedral sheets and alumina octahedral sheets. Imperfections and differences in orientation within this stacking will lead to differences in the kaolinite mineral. Each unit within the montmorillonite stack is composed of two silica tetrahedral sheets sandwiching a alumina octaheldral sheet. Because of the unbalanced forces between sucessive units, polar molecules such as water can enter and distribute the charges. This accounts for the swelling properties of montmorillonite bearing clays. The presence of sodium, calcium, magnesium and iron between units will also affect the degree of swelling. The unit structure of attapulgite is comprised of two silica chains liked by octahedral groups of hydroxyls and oxygens together with aluminum and magnesium. The emperical formula is $(Mg,Al)_5Si_8O_{22}(OH)_4 \bullet 4H_2O$. The unit structure of illite resembles that of montmorillonite except that aluminum ions replace some of the silicon ions. The resultant charge imbalance is neutralized by the inclusion of potassium ions between units.

Most clays are mined from open pits, using modern surface mining equipment such as draglines, power shovels, scraper loaders, and shale planers. A few clay pits are operated using crude hand mining methods. A small number of clay mines (principally underclays in coal mining areas) are underground operations employing mechanized room and pillar methods. Truck haulage from the pits to processing facilities is most common, but other methods involve use of rail transport, conveyor belts, and pipelines in the case of kaolin. Recovery is near 100 percent of the minable beds in open pit mines, and perhaps 75 percent in the underground operations. The waste to clay ratio is highest for kaolin (about 7:1) and lowest for miscellaneous clay (about 0.25:1).

Processing of clays ranges from very simple and inexpensive crushing and screening for some common clays to very elaborate and expensive methods necessary to produce paper coating clays and high quality filler clays for use in rubber, paint, and other products. Waste material from processing consists mostly of quartz, mica, feldspar, and iron minerals.

Clays are classified into six groups by the Bureau of Mines, kaolin, ball clay, fire clay, bentonite, fuller's earth, and miscellaneous clay. Halloysite is included under kaolin in Bureau of Mines statistical reports. Specifications of clays are based on the method of preparation (i.e. crude, air separated, water washed, delaminated, air dried, spray dried, calcined, slip, pulp, slurry, or water suspension), in addition to specific physical and chemical properties. The supply-demand relationships for clays in 1968 are shown in Figure 15.

BENTONITE (SIC 1452)

Bentonites are fine-grained clays containing at least 85 percent montmorillonite. The swelling type has a high sodium ion concentration which causes a material increase in volume when the clay is wetted with water, whereas the nonswelling types usually contain high calcium ion concentrations. Standard grades of swelling bentonite increase from 15 to 20 times their dry volume on exposure to water. Specifications are based on pertinent physical and chemical tests, particularly those relating to particle size and swelling index. Bentonite clays are processed by weathering, drying, grinding, sizing, and granulation.

The principal uses of bentonites are for drilling muds, catalyst manufacture, decolorizing agents, and foundry use. However the properties within the bentonite group vary such

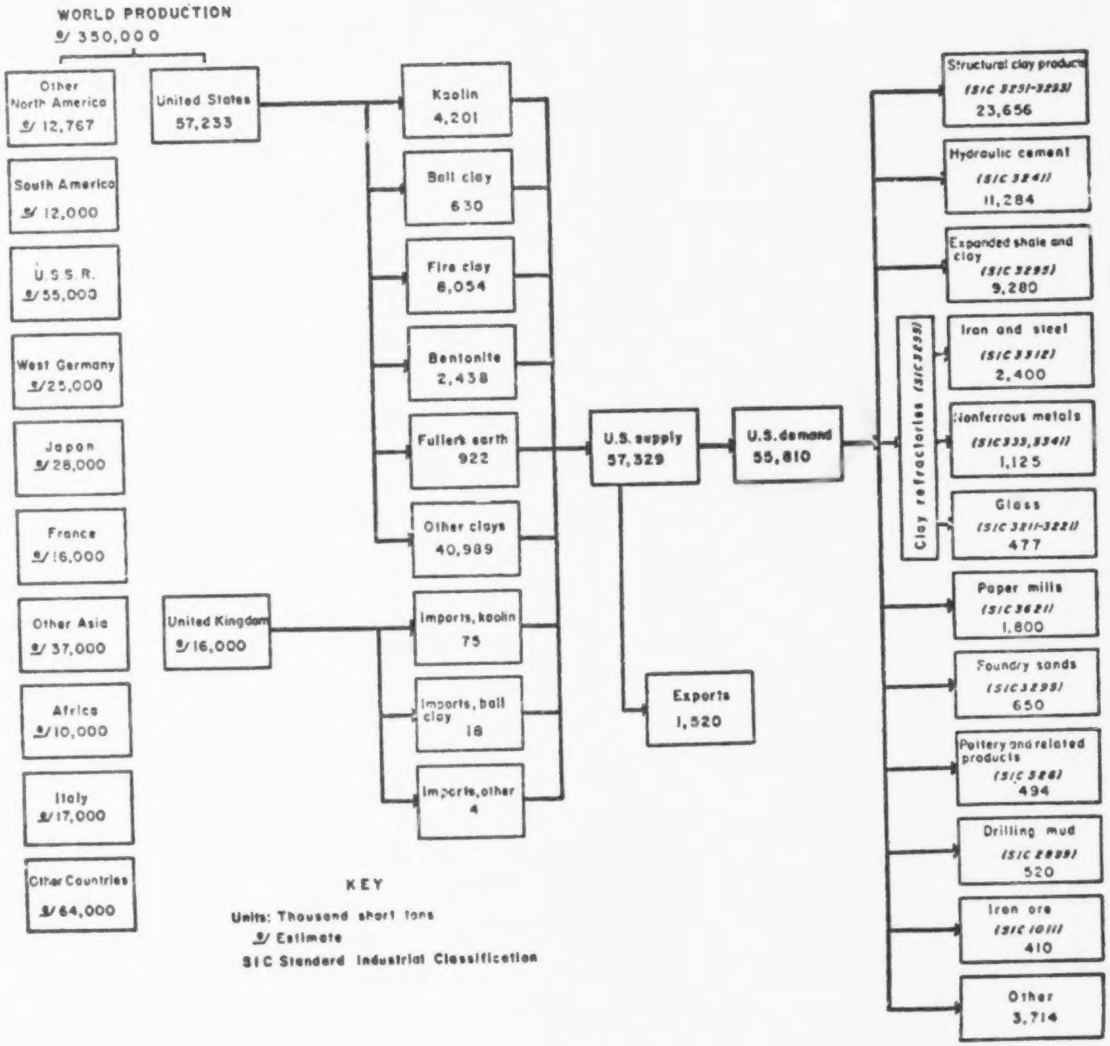

WORLD PRODUCTION
e/ 350,000
Other North America e/ 12,767
South America e/ 12,000
U.S.S.R. e/ 55,000
West Germany e/ 25,000
Japan e/ 28,000
France e/ 16,000
Other Asia e/ 37,000
Africa e/ 10,000
Italy e/ 17,000
Other Countries e/ 64,000
United States 57,233
United Kingdom e/ 16,000
Kaolin 4,201
Ball clay 630
Fire clay 8,054
Bentonite 2,438
Fuller's earth 922
Other clays 40,989
Imports, kaolin 75
Imports, ball clay 18
Imports, other 4
U.S. supply 57,329
Exports 1,520
U.S. demand 55,810
Clay refractories (SIC 3255)
Structural clay products (SIC 3251-3253) 23,656
Hydraulic cement (SIC 3241) 11,284
Expanded shale and clay (SIC 3295) 9,280
Iron and steel (SIC 3312) 2,400
Nonferrous metals (SIC 333, 3341) 1,125
Glass (SIC 3211-3221) 477
Paper mills (SIC 3621) 1,800
Foundry sands (SIC 3295) 650
Pottery and related products (SIC 326) 494
Drilling mud (SIC 2899) 520
Iron ore (SIC 1011) 410
Other 3,714
KEY
Units: Thousand short tons
e/ Estimate
SIC Standard Industrial Classification

Figure 15 Supply-Demand Relationships for Clays, 1968.

that a single deposit cannot serve all the above mentioned functions. Because of the high montmorillonite content, bentonites are an important raw material in producing fuller's earth. The distinction between these two clays is not clearly defined, except by end usage.

The bentonites found in the United States were deposited in the Cretaceous age as fine air-borne volcanic ash. Advancing salt water seas and groundwater had resulted in cationic exchange of iron and magnesium. The placement of the relatively large sodium and calcium ions between the silica and alumina sheets in the basic montmorillonite lattice structure are responsible for the important property of swelling in water. Sodium bentonite is principally mined in Wyoming while calcium bentonite is found in many states, but principally Texas, Mississippi and Arizona.

FIRE CLAY (SIC 1453)

The terms "fire clays" and "stoneware clays" are based on refractoriness or on the intended usage for refractories; hence they are also called refratory clays, and stoneware clay for such items as crocks, jugs, and jars. Their most notable property is their high fusion point. Fire clays are principally kaolinitic containing other clay minerals and impurities such as quartz. Included under the general term fire clay are the diaspore, burley, and burley flint clays. Fire clays are usually plastic in nature and are often referred to as plastic clays, but flint clays are exceedingly hard due to their high content of kaolinite. The fired colors of fire clays range from reds to buffs and grays. Specifications are based on pertinent physical and chemical properties of the clays and of products made from them. In general the higher the alumina content is, the higher the fusion point. Impurities such as lime and iron lower the fusion point. Fire clays are mined principally in Missouri, Illinois, Indiana, Kentucky, Ohio, West Virginia, Pennsylvania and Maryland. Fire clays are processed by crushing, calcining and final blending.

FULLER's EARTH (SIC 1454)

The term "fuller's earth" is derived from the first major use of the material, which was for cleaning wool by fullers. Fuller's earths are essentially montmorillonite or attapulgite for which the specifications are based on the physical and chemical requirements of the products. As previously mentioned the distinction between fuller's earth and bentonite is in the commercial usage. Major uses are for decolorizing oils, beverages, and cat litter. The fuller's earth clays are processed by blunging, extruding, drying, crushing, grinding and finally sizing according to the requirements of its eventual use.

KAOLIN AND BALL CLAY (SIC 1455)

Kaolin is the name applied to the broad class of clays chiefly comprised of the mineral kaolinite. Although the various kaolin clays do differ in chemical and physical properties the main reason for distinction has been commercial usage. Both fire clay and ball clay are kaolinic clays. Kaolin is mined in South Carolina and Georgia and is used as fillers and pigments. Ball clays consist principally of kaolinite, but have a higher silica to alumina ratio than is found in most kaolins in addition to larger quantities of mineral impurities, the presence of minor quantities of montmorillonite and organic material. They are usually much finer grained than kaolins due to their sedimentary origin and set the standards for plasticity of clays. Ball clays are mined in western Kentucky, western Tennessee and New Jersey. Specifications for ball clays are based on methods of preparation (crude, shredded, air floated) and pertinent physical and chemical properties, which are much the same as those for kaolin. The prinicpal use for ball clay is in whitewares (i.e. china).

MISCELLANEOUS CLAYS

Miscellaneous clays may contain some kaolinite and montmorillonite, but usually illite predominates, particularly in the shales. There are no specific recognized grades based on preparation, and very little based on usage, although such a clay may sometimes be referred to as common, brick, sewer pipe, or tile clay. Specifications are based on the physical and chemical characteristics of the products. The environmental considerations are significant, not because the waste products from clay mining are particularly offensive, but because of the large number of operations and the necessity for locating them in or near heavily populated consumption centers.

FELDSPAR (SIC 1459)

Feldspar is a general term used to designate a group of closely related minerals, especially abundant in igneous rocks and consisting essentially of aluminum silicates in combination with varying proportions of potassium, sodium, and calcium. The feldspars are the most abundant minerals in the crust of the earth. The principal feldspar species are orthoclase or microcline (both $K_2O \cdot Al_2O_3 \cdot 6SiO_2$), albite

($Na_2O \cdot Al_2O_3 \cdot 6SiO_2$), and anorthite ($CaO \cdot Al_2O_3 \cdot 2SiO_2$). Specimens of feldspar closely approaching the ideal compositions are seldom encountered in nature, however, and nearly all potash feldspars contain significant proportions of soda. Albite and anorthite are really the theoretical end members of a continuous compositional series known as the plagioclase feldspars, none of which, moreover, is ordinarily without at least a minor amount of potash.

Originally, only the high potash feldspars were regarded as desirable for most industrial purposes. At present, however, in many applications the potash and the soda varieties, as well as mixtures of the two, are considered to be about equally acceptable. Perthite is the name given to material consisting of orthoclase or microcline, the crystals of which are intergrown to a variable degree with crystals of albite. Most of the feldspar of commerce can be classified correctly as perthite. Anorthite and the plagioclase feldspars are of limited commercial importance.

Until a few decades ago virtually all the feldspar employed in industry was material occurring in pegmatite deposits as massive crystals pure enough to require no treatment other than hand cobbing to bring it to usable grade. More recently, however, stimulated by the often unfavorable location of the richer pegmatite deposits relative to markets and by the prospect of eventual exhaustion of such sources, more than 90 percent of the total current domestic supply is extracted from such feldspar bearing rocks as alaskite and from beach sands. A large part of the material obtained from beach sands is in the form of feldspar silica mixtures that can be used, with little or no additional processing, as furnace feed ingredients in the manufacture of glass. In fact, this use is so prominent that feldspathic sands are considered under industrial sands.

Nepheline syenite is a feldspathic, igneous rock which contains little or no free silica, but does contain nepheline ($K_2O \cdot 3Na_2O \cdot 4Al_2O_3 \cdot 9SiO_2$). The valuable properties of nepheline are the same as those of feldspar, therefore, nepheline syenite, being a mixture of the two, is a desirable ingredient of glass, whiteware and ceramic glazes and enamels. A high quality nepheline syenite is mined in Ontario, Canada, and is being imported into the U.S. in ever increasing quantities for ceramics manufacture. Deposits of the mineral exist in the U.S. in Arkansas, New Jersey, and Montana, but mining occurs only in Arkansas, just outside of Little Rock. There, the mineral is mined in open pits as a secondary product to crushed rock. Since this is the only mining of this material in the U.S. it will not be considered further.

Rocks that are high in feldspar and low in iron and that have been mined for the feldspar content have received special names, for instance aplite (found near Piney River, Virginia), alaskite (found near Spruce Pine, North Caroline) and perthite. The major feldspar producing states are North Carolina, Calfironia, the New England states, Colorado and South Dakota.

Feldspar and feldspathic materials in general are mined by various systems depending upon the nature of the deposits being exploited. Because underground operations entail higher costs, as long as the overburden ratio will permit and land use conflicts are not a decisive factor, most feldspathic rocks will continue to be quarried by open pit procedures using drills and explosives. Feldspathic sand deposits are mined by dragline excavators. High grade, selectively mined feldspar from coarse structured pegmatites can be crushed in jaw crushers and rolls and then subjected to dry milling in flint lined pebble mills.

Feldspar ores of the alaskite type are mostly beneficiated by froth flotation processes. The customary procedure begins with primary and secondary comminution and fine grinding in jaw crushers, cone crushers, and rod mills, respectively. The sequence continues with acid circuit flotation in three stages, each stage preceded by desliming and conditioning. In the first flotation step an amine collector floats off mica, and the second uses sulfonated oils to separate iron bearing minerals. The third step floats the feldspar with another amine collector, leaving behind a residue that consists chiefly of quartz.

KYANITE (SIC 1459)

Kyanite and the related minerals, andalusite, sillimanite, dumortierite, and topaz, are natural aluminum silicates which can be converted by heating to mullite, a stable refractory raw material with some interstitial glass also being formed. Kyanite, and alusite and sillinanite have the basic formula $Al_2O_3.SiO_2$. Dumortierite contains boron, and topaz contains fluorine, both of which vaporize during the conversion to mullite ($3Al_2O_3.2SiO_2$).

With the exception of the production of a small amount of by-product kyanite and sillimanite from Florida heavy mineral operations, the bulk of domestic kyanite production is derived from two mining operations in Virginia, operated by the same company, and one in Georgia. The mining and process methods used by these producers are basically the same. Mines are open pits in which the hard rock must be blasted loose. The ore is hauled to the nearby facilities in trucks where the ore is crushed and then reduced in rodmills. Three stage flotation is used to obtain a kyanite concentrate. This product is further treated by magnetic separation to remove most of the magnetic iron. Some of the concentrate is marketed as raw kyanite, while the balance is further ground and/or calcined to produce mullite.

Florida beach sand deposits are worked primarily for zircon and titanium minerals, but the tailings from the zircon recovery units contain appreciable quantities of sillimanite and kyanite, which can be recovered by flotation and magnetic separations. Production and marketing of Florida sillimanite and kyanite concentrates started in 1968. The principal end uses for kyanite are iron and steel, primary nonferrous metals, secondary non-ferrous metals, boilers and glass.

MAGNESITE (SIC 1459)

Magnesium is the eighth most plentiful element in the earth and, in its many forms, comprises about 2.06 percent of the earth's crust. Although it is found in 60 or more minerals, only four, dolomite, magnesite, brucite, and olivine, are used commercially to produce magnesium compounds. Currently dolomite is the only domestic ore used as principal raw material for producing magnesium metal. Sea water and brines are also principal sources of magnesium. It is the third most abundant element dissolved in sea water, averaging 0.13 percent magnesium by weight. Extraction of magnesium from sea water is so closely associated with the manufacture of refractories that it is discussed in the clay and gypsum products point source category.

Dolomite is the double carbonate of magnesium and calcium, and is a sedimentary rock commonly interbedded with limestone, extending over large areas of the United States. Most dolomites probably result from the replacement of calcium by magnesium in preexisting limestone beds. Magnesite, the natural form of magnesium carbonate, is found in bedded deposits, as deposits in veins, pockets, and shear zones in ferro-magnesium rocks, and as replacement bodies in limestone and dolomite. Significant deposits occur in Nevada, California, and Washington. Brucite, the natural form of magnesium hydroxide, is found in crystalline limestone and as a decomposition product of magnesium silicates associated with serpentine, dolomite, magnesite, and chromite. Olivine, or chrystolite, is a magnesium iron silicate usually found in association with other igneous rocks such as basalt and gabbro. It is the principal constituent of a rock known as dunite. Commercial deposits occur in Washington, North Carolina, and Georgia.

Evaporites are deposits formed by precipitation of salts from saline solutions. They are found both on the surface and underground. The Carlsbad, New Mexico, and the Great Salt Lake evaporite deposits are sources of magnesium compounds. The only significant commercial source of magnesium compounds from well brines is in Michigan, although brines are known to occur in many other areas. This form of mining is included in the clay, gypsum, ceramics and refractory products report since it is closely related to refractories manufacturing.

Selective open-pit mining methods are being used to mine magnesite at Gabbs, Nevada. This facility is the only known U.S. facility that produces magnesia from naturally occurring magnesite ore.

Magnestie and brucite ore are delivered from the mines to gyratory or jaw crushers where it is reduced to a minus 13 centimeter (5 inch) size. It is further crushed to minus 6.4 centimeters (2.5 inches) and conveyed to storage piles. Magnesite ore is either used directly or beneficiated by heavy media separation or froth flotation. Refractory magnesia is produced by blending, grinding and briquetting various grades of magnesite with certain additives to provide the desirable refractory product. The deadburning takes place in rotary kilns which develop temperatures in the range of 1490-1760°C (2700 to 3200°F).

When the source of magnesia is sea water or well brine, the waters are treated with calcined dolomite or lime obtained from oyster shell by calcining, to precipitate the magnesium as magnesium hydroxide. The magnesium hydroxide slurry is filtered to remove water, after which it is conveyed to rotary kilns fired to temperatures that may be as high as 1850°C (3,360°F). The calcined product contains approximately 97 percent MgO. The principal uses for magnesium compounds follow:

Compound and grade	Use
Magnesium oxide:	
Refractory grades	Basic refractories.
Caustic-calcined	Cement, rayon, fertilizer, insulation, magnesium metal, rubber, fluxes, refractories, chemical processing and manufacturing, uranium processing, paper processing.
U.S.P. and technical	Rayon, rubber (filler and

grades	catalyst), refractories, medicines, uranium processing, fertilizer, electrical insulation, neoprene compounds and other chemicals, cement.
Precipitated magnesium carbonate	Insulation, rubber pigments and paint, glass, ink, ceramics, chemicals, fertilizers.
Magnesium hydroxide	Sugar refining, magnesium oxide, pharmaceuticals.
Magnesium chloride	Magnesium metal, cement, ceramics, textiles, paper, chemicals.

Basic refractories used in metallurgical furnaces are produced from magnesium oxide and accounted for over 80 percent ot total domestic demand for magnesium in 1968. Technological advances in steel production required higher temperatures which were met by refractories manufactured from high purity magnesia capable of withstanding temperatures above 1930°C (3,500°F).

SHALE AND OTHER CLAY MINERALS (SIC 1459)

SHALES

Shale is a soft laminated sedimentary rock in which the constituent particles are predominantly of the clay grade. Just as clay possesses varying properties and uses, the same can be said of shale. Thus, the word shale does not connote a single mineral, inasmuch as the properties of a given shale are largely dependent on the properties of the originating clay species. The mining of shales depends on the nature of the specific deposit and on the amount and nature of the overburden. While some deposits are mined underground, the majority of shale deposits are worked as open quarries.

Shales and common clays are used interchangeably in the manufacture of formed and fired ceramic products and are frequently mixed prior to processing for optimization of product properties. Ceramic products consume about 70 percent of the shale production. Certain impure shales (and clays) have the property of expanding to a cellular mass when rapidly heated to 1000 - 1300°C. On sudden cooling, the melt forms a porous slag like material which is screened to produce a lightweight concrete aggregate with a density of 960-1800 kg/m^3 (60-110 lb/ft.^{3}). Probably 20 to 25 percent of the total market for shale goes into aggregate production.

APLITE

Aplite is a granitic rock of variable composition with a high proportion of soda or lime soda feldspar. It is therefore useful as a raw material for the manufacture of container glass. Processing of the ore primarily achieves particle size reduction and removal of all but a very small fraction of iron bearing minerals. Aplite is produced in the U.S. from only two mines, both in Virginia (Nelson County and Hanover County). The aplite rock in Hanover County has been decomposed so completely that it is mined without resort to drilling or blasting.

TALC, STEATITE, SOAPSTONE AND PYROPHYLLITE (SIC 1496)

The mineral talc is a soft, hydrous magnesium silicate, $3MgO \cdot 4SiO_2 \cdot H_2O$. The talc of highest purity is derived from sedimentary magnesium carbonate rocks; less pure talc from ultra basic igneous rocks.

Steatite has been used to designate a grade of industrial talc that is especially pure and is suitable for making electronic insulators. Block steatite is a massive form of talc that can be readily machined, has a uniform low shrinkage in all directions, has a low absorption when fired at high temperature, and gives proper electrical resistance values after firing. Phosphate bonded talc which is approximately equivalent to natural block can be manufactured in any desired amount. French chalk is a soft, massive variety of talc used for marking cloth.

Soapstones refer to the sub-steatite, massive varieties of talc and mixtures of magnesium silicates which with few exceptions have a slippery feeling and can be carved by hand.

Pyrophyllite is a hydrous aluminum silicate similar to talc in properties and in most applications, and its formula is $Al_2O_3 \cdot 4SiO_2 \cdot H_2O$. It is principally found in North Carlina. Wonderstone is a term applied to a massive block pyrophyllite from the Republic of South Africa. The uses of pyrophyllite include wall tile, refractories, paints, wallboard, insecticides, soap, textiles, cosmetics, rubber, composition battery boxes and welding rod coatings.

During 1968 talc was produced from 52 mines in Alabama, California, Georgia, Maryland, Montana, Nevada, New York, North Carolina, Texas, and Vermont. Soapstone was produced from 13 mines in Arkansas, California, Maryland, Nevada, Oregon, Virginia, and Washington. Pyrophyllite was produced from 10 mines in California and North Carolina. Sericite schist, closely resembling pyrophyllite in physical and chemical properties, was produced in Pennsylvania and included with the pyrophyllite statistics.

The facility size breakdown is as follows:

Numbers of Facilities	Production tons/yr
6	< 1,000
22	1,000 - 10,000
20	10,000 - 100,000
3	100,000 - 1,000,000

Slightly more than half of the industrial talc is mined underground and the rest is quarried as is soapstone and pyrophyllite. Small quantities of block talc also are removed by surface methods. Underground operations are usually entirely within the ore body and thus require timber supports that must be carefully placed because of the slippery nature of the ore.

Mechanization of underground mines has become common in recent years, especially in North Carolina and California where the ore body ranges in thickness from 3 to 4.6 meters (10 to 15 ft) and dips 12 to 19 degrees from horizontal. In those mines where the ore body suffers vein dips of greater than 20 degrees, complex switchbacks are introduced to provide the gentle slopes needed for easier truck haulage of the ore. At one quarry in Virginia, soapstone for decorative facing is mined in large blocks approximately 1.2 by 2.4 by 3.0 meters (4 by 8 by 10 ft) which are cut into slices by gang saws with blades spaced about 7.6 cm (3 in) apart. In the mining of block talc of crayon grade, a minimum of explosive is used to avoid shattering the ore; extraction of the blocks is done with hand equipment to obtain sizes as large as possible.

When mining ore of different grades within the same deposit, selective mining and hand sorting must be used. Operations of the mill and mine are coordinated, and when a certain specification is to be produced at the mill, the desired grade of ore is obtained at the mine. This type of mining and/or hand sorting is commonly used for assuring the proper quality of the output of crude talc group minerals.

Roller mills, in closed circuit with air separators, are the most satisfactory for fine grinding (100 to 325 mesh) of soft talcs or pyrophyllites. For more abrasive varieties, such as New York talc and North Carolina ceramic grade pyrophyllite, grinding to 100 to 325 mesh is effected in quartzite or silex lined pebble mills, with quartzite pebbles as a grinding medium. These mills are ordinarily in closed circuit with air separators but sometimes are used as batch grinders, especially if reduction to finer particle sizes is required.

Talc and pyrophyllite are amenable to processing in an additional microgrinding apparatus. Microgrinding or micronizing is also done in fluid systems with subsequent air drying of the product. The principal end uses for talc and its related minerals are ceramics, paint, roofing, insecticides, paper, refractories, rubber and toilet preparations.

NATURAL ABRASIVES (SIC 1499)

Abrasives consist of materials of extreme hardness that are used to shape other materials by grinding or abrading action. Such materials may be classified as either natural or synthetic. Of interest here are the natural abrasive minerals cleamorid, corundum, emery, pumice, tripoli and garnet. Of lesser importance are feldspar, calcined clays, chalk and silica in its many forms such as sandstones, sand, flint and diatomite. Abrasive sand is covered in industrial sand.

CORUNDUM

Corundum is a mineral with the composition Al_2O_3 that was crystallized in a hexagonal form by igneous and metamorphic processes. Abrasive grade corundum has not been mined in the United States for more than 60 years. There is no significant environmental problem posed by the processing of some 2,360 kkg of imported corundum per year (1968 data), and further consideration will be dropped.

EMERY

Emery consists of an intimate admixture of corundum with magnetite or hematite, and spinel. The major domestic use of emery involves its incorporation into aggregates as a rough ground product for use as heavy duty, non-skid flooring and for skid resistant highways. Additional quantities (25 percent of total consumption) are used in general abrasive applications. Recent statistics show the continuing downturn in demand for emery resulting from the increasing competition with such artificial abrasives as Al_2O_3 and SiC. Production is estimated to be 11,000 kkg/yr (10,000 tons/yr). Emery is not considered further in this report because it is not economically significant and no environmental problems are noted.

TRIPOLI

Tripoli is the generic name applied to a number of fine grained, lightweight, friable, minutely porous, forms of decomposed siliceous rock, presumably derived from siliceous limestones or calcareous cherts. Tripoli is often confused, in both the trade and technical literature, with tripolite, a diatomaceous earth (diatomite) found in Tripoli, North Africa.

The two major working deposits of tripoli occur in the Seneca, Missouri area and in southern Illinois. The Missouri ore resembles tripolite and was incorrectly named tripoli. This name has persisted for the ore from the Missouri-Oklahoma field. The material from the southern Illinois area is often refered to as "amorphous" or "soft" silica. In both cases the ore contains 97 to 99 percent SiO_2 with minor additions of alumina, iron, lime, soda and potash. The rottenstone obtained from Pennsylvania is of higher density and has a composition approximately 60 percent silica, 18 percent alumina, 9 percent iron oxides, 8 percent alkalies and the remainder lime and magnesia.

Tripoli mining involves two different processes depending on the nature of the ore and of the overburden. In the Missouri-Oklahoma area, the shallow overburden of approximately 2 meters (six ft) in thickness coupled with tripoli beds ranging from 0.6 to 4.3m (2 to 14 ft) in thickness, lends itself to open pit mining. The tripoli is first hand sorted for texture and color, then piled in open sheds to air dry (the native ore is saturated with water) for three to six months. The dried material is subsequenly crushed with hammer mills and rolls.

In the southern Illinois field, due to the terrain and the heavy overburden, underground mining using a modified room-and-pillar method is practiced. The resulting ore is commonly wet milled after crushing to 0.63 to 1.27 cm (0.25 to 0.50 in); the silica is fine ground in tube mills using flint linings and flint pebbles in a closed circuit system with bowl classifiers. The resulting sized product is thickened, dried and packed for shipment.

Tripoli is primarily used as an abrasive or as a constituent of abrasive materials polishing and buffing copper, aluminum, brass and zinc. In addition, the pulverized product is widely used as the abrasive element in scouring soaps and powders, in polishes for the metal working trades and as a mild mechanical cleaner in washing powders for fabrics. The pure white product from southern Illinois, when finely ground, is widely used as a filler in paint. The other colors of tripoli are often used as fillers in the manufacture of linoleum, phonograph records, and pipe coatings. Total U. S. production of tripoli in 1971 was of the order of 68,000 kkg, some 70 percent of which was used as an abrasive, the remainder as filler.

GARNET

Garnet is an orthosilicate having the general formula $3RO \cdot X_2O_3 \cdot 3SiO_2$ where the bivalent element R may be calcium, magnesium, ferrous iron or manganese; the trivalent element X, aluminum, ferric iron or chromium, rarely titanium; further, the silicon is occasionally replaced by titanium.

The members of the garnet group of minerals are common accessory minerals in a large variety of rocks, particularly in gneisses and schists. They are also found in contact metamorphic deposits, in crystalline limestones; pegmatites; and in serpentines. Although garnet deposits are located in almost every state of the United States and in many foreign countries, practically the entire world production comes from New York and Idaho. The Adirondack deposit consists of an alamandite garnet having incipient lamellar parting planes which cause it to break under pressure into thin chisel edge plates. Even when crushed to very fine size this material still retains this sharp slivery grain shape, a feature of particular importance in the coated abrasive field.

The New York mine is worked by open quarry methods. The ore is quarried in benches about 10.7 m (35 ft) in height, trucked to the mill and dumped on a pan conveyor feeding a 61 - 91 cm (24 x 36 in) jaw crusher. The secondary crusher which is a standard 4 foot Symonds cone is in closed circuit with a 1-1/2 inch screen. The minus 3.8 cm (1 1/2 in) material is screened on a 10 mesh screen. The oversize from the screen goes to a heavy media separation facility while the undersize is classified and concentrated on jigs. The very fine material is treated by flotation. The combined concentrates, which have a garnet content of about 98 percent, are then crushed, sized and heat treated. It has been found that heat treatment, to about 700 to 800° C will improve the hardness, toughness, fracture properties and color of the treated garnets.

The only other significant production of garnets in the United States is situated on Emerald Creek in Benewah County, Idaho. This deposit is an alluvial deposit of alamandite garnets caused by the erosion of soft mica schists in which the garnets have a maximum grain size of about 4.8 mm (3/16 in). The garnet bearing gravel is mined by drag line, concentrated on trommels and jigs then crushed and screened into various sizes. This garnet is used mainly for sandblasting and as filtration media.

Approximately 45 percent of the garnet marketed is used in the manufacture of abrasive coated papers, about 35 percent in the glass and optical industries and the remainder for sand blasting and miscellaneous uses.

DIATOMITE (SIC 1499)

Diatomite is a siliceous rock of sedimentary origin which may vary in the degree of consolidation, but which consists mainly of the fossilized remains of the protective silica shells formed by diatoms, single celled non-flowering microscopic plants. The size, shape and structure of the individual fossils and their mass packing characteristics result in microscopic porous material of low specific gravity.

There are numerous sediments which contain diatom residues, admixed with substantial amounts of other materials including clays, carbonates or silica; these materials are classified as diatomaceous silts, shales or mudstones; they are not properly diatomite, a designation restricted to material of such quality that it is suitable for commercial uses. The terms diatomaceous earth and kieselgur are synonymous with diatomite; the terms infusorial earth and tripolite are considered obsolete. Diatomaceous silica is the most appropriate designation of the principal component of diatomite. Commercially useful deposits of diatomite show SiO_2 concentrations ranging from a low of 86 percent (Nevada) to a high of 90.75 percent (Lompoc, California) for the United States producers; the SiO_2 content of foreign sources is somewhat lower. The remainder consists of alumina, iron oxide, titanium oxide, and lesser quantities of phosphate, magnesia, and the alkali metal oxides. In addition, there is usually some residual organic matter as indicated by ignition losses which are typically of the order of 4 to 5 percent.

The formation of diatomite sediments was dependent upon the existence of the proper environmental conditions over an adequate period of time to permit a significant accumulation of the skeletal remains. These conditions include a plentiful supply of nutrients and dissolved silica for colony growth and the existence of relatively quiescent physical conditions such as exist in protected marine estuaries or in large inland lakes. In addition, it is necessary that these conditions existed in relatively recent times in order that subsequent metamorphic processes would not have altered the diatomite to the rather more indurated materials such as porcelanite and the opaline cherts.

The upper tertiary period was the period of maximum diatom growth and subsequent deposit formation. The great beds near Lompoc, California are upper Miocene and lower Pliocene (about 20 million years old); formations of similar origin and age occur along the California coast line from north of San Francisco to south of San Diego. Most of the dry lake deposits of California, Nevada, Oregon and Washington are of freshwater origin formed in the later tertiary of the Pleistocene age (less than 12 million years old).

Currently, the only significant production of diatomite within the U.S. is in the western states, with California the leading producer, followed by Nevada, Oregon and Washington. Commonly, beds of ordinary sedimentary rocks such as shales, sandstones, or limestone overlie and underlie the diatomite beds; thus the first step in mining requires the removal of the overburden, which ranges from zero to about 15 times the thickness of the diatomite bed, by ordinary earth moving machinery. The ore is ordinarily dug by power shovels usually without the necessity of previous fragmentation by drilling or blasting.

Initial processing of the ore involves size reduction by a primary crusher followed by further size reduction and drying (some diatomite ores contain up to 60 percent water) in a blower hammer mill combination with a pneumatic feed and discharge system. The suspended particles in the hot gases pass through a series of cyclones and a baghouse where they are separated into appropriate particle size groups.

The uses of diatomite result from the size (from 10 to greater than 500 microns in diameter), shape (generally spiny structure of intricate geometry) and the packing characteristics of the diatom shells. Since physical contact between the individual fossil shells is chiefly at the outer points of the irregular surfaces, the resulting compact material is microscopically porous with an apparent density of only 80 to 260 kg/m^3 (5 to 16 lbs/ft^3) for ground diatomite. The processed material has dimensional stability to temperatures of the order of 400° C. The principal end uses for diatomite are thermal insulation, industrial and municipal water treatment, and food, beverage and pharmaceutical processing.

GRAPHITE (SIC 1499)

Natural graphite is the mineral form of elemental carbon, crystallized predominately in the hexagonal system and found in silicate minerals of varying kind and percentage. The three principal types of natural occurrence of graphite are classified as lump, amorphous and crystalline flake, based on major differences in geologic origin and occurrence.

Lump graphite occurs as fissure filled veins wherein the graphite is typically massive with particle size ranging from extremely fine grains to coarse, platy intergrowths or fibrous to acicular aggregates. The origin of vein type deposits is believed to be either hydrothermal or pneumatolytic since there is no apparent relationship between the veins and the host rock. A variety of minerals generally in the form of isolated pockets or grains, occur with graphite, including feldspar, quartz, mica, pyroxene, zircon, rutile, apatite and iron sulfides.

Amorphous graphite, which is fine grained, soft, dull black, earthy looking and ususally somewhat porous, is formed by metamorphism of coalbeds by nearby intrusions. Although the purity of amorphous graphite depends on the purity of the coalbeds from which it was derived, it is usually associated with sandstones, shales, slates and limestones and contains accessory minerals such as quartz, clays and iron sulfides.

Flake graphite, which is believed to have been formed by metamorphism from sedimentary carbon inclusions within the host rocks, commonly occurs disseminated in regionally metamorphosed sedimentary rocks such as gneisses, schists and marbles. The only domestic producer is located near Burnet, Texas and mines the flake graphite by open pit methods utilizing a 5.5 m (18 ft) bench pan. The ore is hard and tough and thus requires much secondary blasting. The broken ore is hauled by motor trucks to the mill.

Because of the premium placed upon the mesh size of flake graphite, the problem in milling is one of grinding to free the graphite without reducing the flake size excessively; this is difficult because during grinding, the graphite flakes are cut by quartz and other sharp gangue materials, thus rapidly reducing the flake size. However, if the flake can be removed from most of the quartz and other sharp minerals soon enough, subsequent grinding will usually reduce the size of the remaining gangue with little further reduction in the size of the flake. Impact grinding or ball milling reduces flake size rather slowly, the grinding characteristics of flake graphite under these conditions being similar to those of mica.

Graphite floats readily and does not require a collector; hence, flotation has become the accepted method for beneficiating disseminated ores. Although high recoveries are common, concentrates with acceptable graphitic carbon content are difficult to attain and indeed with some ores impossible. The chief problem lies with the depression of the gangue minerals since relatively pure grains of quartz, mica, and other gangue minerals inadvertently become smeared with fine graphite, making them floatable and resulting in the necessity for repeated cleaning of the concentrates to attain high grade products. Regrinding a rougher concentrate reduces the number of cleanings needed. Much of the natural flake either has a siliceous skeleton (which can be observed when the carbon is burned) or is composed of a layer of mica between outer layers of graphite making it next to impossible to obtain a high grade product by flotation.

MISCELLANEOUS NON-METALLIC MINERALS
(SIC 1499)

JADE

The term jade is applied primarily to the two minerals jadeite and nephrite, both minerals being exceedingly tough with color varying from white to green. Jadeite, which is a sodium aluminum silicate ($NaAlSi_2O_6$) contains varying amounts of iron, calcium and magnesium is found only in Asia. Nephrite is a tough compact variety of the mineral tremolite ($Ca_2Mg_5Si_8O_{22}(OH)_2$) which is an end member of an isomorphous series wherein iron may replace magnesium. In the U.S. production of jade minerals is centered in Wyoming, California and Alaska.

NOVACULITE

Novaculite is a generic name for massive and extensive geologic formations of hard, compact, homogenous, microcrystalline silica located in the vicinity of Hot Springs, Arkansas. There are three strata of novaculite --- lower, middle, and upper. The upper strata is not compacted and is a highly friable ore which is quarried, crushed, dried and air classified prior to packaging. Chief uses are as filler in plastics, pigment in paints, and as a micron sized metal polishing agent.

WHETSTONE

Whetstones, and other sharpening stones, are produced in small volume across the U.S. wherever deposits of very hard silaceous rock occur. However, the largest center of sharpening stone manufacture is in the Hot Springs, Arkansas, area. This area has extensive out-cropping deposits of very hard and quite pure silica, called "Novaculite", which are mined and processed into whetstones. Most of the mining and processing is done on a very small scale by individuals or very small companies. The total production in 1972 of all special silica stone products (grinding pebbles, grindstones, oilstones, tube-mill liners, and whetstones) was only 2,940 kkg (3,240 tons) with a value of $670,000. This production is neither economically nor environmentally significant and will not be treated further in this report.

SECTION IV

INDUSTRY CATEGORIZATION

The first cut in subcategorization was made on a commodity basis. This was necessary because of the large number of commodities and to avoid insufficient study of any one area. Furthermore, the economics of each commodity differ and an individual assessment is necessary to insure that the economic impact is not a limiting factor in establishing effluent treatment technologies. Table 10 lists the subcategories in this report.

Manufacturing Processes

Each commodity can be further subcategorized into three very general classes - dry crushing and grinding, wet crushing and grinding (shaping), and crushing and beneficiation (including flotation, heavy media, et al). Each of these processes is described in detail in Section V of this report. The type of manufacturing process can significantly affect the amount and type of pollutants generated and their treatability. It can therefore be a basis for further subcategorization. Water from the mine, such as mine pumpout and runoff, is considered separately from process water unless the two are technically or economically inseparable.

Raw Materials

The raw materials used are principally ores which vary across this segment of the industry and also vary within a given deposit. Despite these variations, differencies in ore grades do not generally affect the ability to achieve the effluent limitations. In cases where it does, different processes are used, and subcategorization is better applied by process type as described in the above paragraph.

Product Purity

The mineral extraction processes covered in this report yield products which vary in purity from what would be considered a chemical technical grade to an essentially analytical reagent quality. Pure product manufacture usually generates more waste than the production of lower grades of material, and thus could be a basis for subcategorization. As is the case for variation of ore grade discussed under raw materials previously, pure

TABLE 10
Industry Categorization

Commodity	SIC Code	Subcategory
Dimension Stone	1411	No further subcategorization
Crushed Stone	1422, 1423, 1429, 1499	Dry Wet Flotation
Construction Sand and Gravel	1442	Dry Wet Dredging, on-land processing Dredge water plant intake water
Industrial Sand	1446	Dry and Wet Processing Acid Leaching Flotation (acid and alkali) Flotation (HF)
Gypsum	1492	Dry Dry, wet scrubbers HMS
Asphaltic Minerals	1499	Bituminous limestone Oil impregnated diatomite Gilsonite
Asbestos and Wollastonite	1499	Asbestos, Dry Asbestos, Wet Wollastonite
Lightweight Aggregates	1499	Perlite Pumice Vermiculite
Mica and Sericite	1499	Dry Wet Wet beneficiation either no clay or general purpose clay by-product Wet beneficiation cer. gr. by-product
Barite	1472, 3295	Dry Wet Flotation
Fluorspar	1473, 3295	Heavy media separation Flotation Drying and Pelletizing
Salines from Brine Lakes	various	No further subcategorization
Borax	1474	No further subcategorization
Potash	1474	No further subcategorization
Trona	1474	No further subcategorization
Sodium Sulfate	1474	No further subcategorization
Rock Salt	1476	No further subcategorization
Phosphate Rock	1475	Flotation units Non-flotation units
Sulfur (Frasch)	1477	Anhydrite On-shore Off-shore
Mineral Pigments	1479	No further subcategorization
Lithium Minerals	1479	No further subcategorization
Bentonite	1452	No further subcategorization
Fire Clay	1453	No further subcategorization
Fuller's Earth	1454	Attapulgite Montmorillonite
Kaolin	1455	Dry Kaolin mining and processing Kaolin mining and wet processing for high-grade product
Ball Clay	1455	Ball clay - dry processing Ball clay - wet processing
Feldspar	1459	Feldspar wet processing Feldspar dry processing
Kyanite	1459	No further subcategorization
Magnesite	1459	No further subcategorization
Shale & Common Clay, NEC	1459	Shale and common clay Aplite
Talc Minerals Group	1496	Talc minerals group, dry process Talc minerals Group, ore mining & washing Talc minerals group, ore mining, heavy media and flotation
Natural Abrasives	1499	Garnet Tripoli
Diatomite	1499	No further subcategorization
Graphite	1499	No further subcategorization
Misc. Minerals, Not Elsewhere Classified	1499	Jade Novaculite

products usually result from different beneficiation processes, and subcategorization is better applied there.

Facility Size

For this segment of the industry, information was obtained from more than 600 different mineral mining sites. Capacity varied from as little as 1 to 12,500 kkg/day. Setting standards based on kg pollutant per kkg of production minimizes the differences in facility sizes. The economic impact on facility size is addressed in the economic analysis study.

Facility Age

The newest facility studied was less than a year old and the oldest was 150 years old. There is no correlation between facility age and the ability to treat process waste water to acceptable levels of pollutants. Also the equipment in the oldest facilities either operates on the same principle or is identical to equipment used in modern facilities. Therefore, facility age was not an acceptable criterion for categorization.

SECTION V

WATER USE AND WASTE CHARACTERIZATION

Waste water originates in the mineral mining and processing industry from the following sources.

(1) Non-contact cooling water
(2) Process generated water - wash water
    transport water
    scrubber water
    process and product consumed water
    miscellaneous water
(3) Auxiliary process water
(4) Storm and ground water - mine dewatering
    mine runoff
    plant runoff

Non-contact cooling water is defined as that cooling water which does not come into direct contact with any raw material, intermediate product, by-product or product used in or resulting from the process or any process water. The largest use of non-contact cooling water is for the cooling of crusher bearings, dryers, pumps and air compressors.

Process generated waste water is defined as that water which, in the mineral processing operations such as crushing, washing, and benefication, comes into direct contact with any raw material, intermediate product, by-product or product used in or resulting from the process. Examples of process generated waste water follow. Insignificant quantities of contact cooling water are used in this segment of the mineral mining industry. When used, it usually either evaporates or remains with the product. Wash water is used to remove fines and for washing of crushed stone, sand and gravel. Water is widely used in the mineral mining industry to transport ore between various process steps. Water is used to move crude ore from mine to mill, from crushers to grinding mills and to transport tailings to final retention ponds. Particularly in dry processing wet scrubbers are used for air pollution control. These scrubbers are primarily used on dryers, grinding mills, screens, conveyors and packaging equipment. Product consumed water is often evaporated or shipped with the product as a slurry or wet filter cake. Miscellaneous water uses vary widely among the facilities with general usage for floor washing and cleanup. The general practice is to discharge such streams without treatment or combine them with process water prior to treatment. Another

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miscellaneous water use in this industry involves the use of sprays to control dust at crushers, conveyor transfer points, discharge chutes and stockpiles. This water is usually low volume and is either evaporated or adsorbed on the ore.

Auxiliary process water is defined as that used for processes necessary for the manufacture of a product but not contacting the process materials, for example influent water treatment. Auxiliary process water includes blowdowns from cooling towers, boilers and water treatment. The volume of water used for these purposes in this industry is minimal.

Water will enter the mine area from three natural sources, direct precipitation, storm runoff and ground water intrusion. Water contacting the exposed ore or disturbed overburden will be contaminated. Storm water and runoff can also become contaminated at the processing site from storage piles, process equipment and dusts that are emitted during processing. Plant runoff that does not co-mingle with process waste water is not process waste water. This includes storage pile runoff.

The quantity of water usage ranges from 0 to 726,400,000 l/day (191,900,000 gal/day). In general, the facilities using very large quantities of water use it for heavy media separation, flotation, wet scrubbing and non-contact cooling.

DIMENSION STONE (SIC 1411)

The quarrying of dimension stone can be accomplished using one of six primary techniques. Some can be used singly; most are used in various combinations. These techniques, their principal combinations, and their areas of use, are discussed as follows:

(1) Drilling, with or without broaching, is done dry or wet. On occasion, shallow drilling of holes a few centimeters apart is the prelude to insertion of explosive charges, or to insertion of wedges, or wedges with two especially shaped iron strips ("plugs-and-feathers"). On other occasions, drilling deeper holes, followed by removal of stone between holes (broaching) is the primary means of stone cutting. Drilling is either dry or wet with water serving to suppress dust, to wash away stone chips from the working zone, and to keep the drills cool and prolong the cutting edge. Drilling to some extent is necessary in virtually all dimension stone quarrying.

(2) Channel machines are simple, long, semi-automated, multiple-head chisels. They are electrically or steam powered (with the steam generating unit an integral part of each machine), and are primarily used on limestone along with other techniques. The machines are always used with water, primarily to remove stone chips which are formed by machine action.

(3) Wire sawing is another technique requiring the use of water. Generally, a slurry of hard sand or silicon carbide in water is used in connection with the saw. The use of wire saws is probably not justified in small quarries, as the initial setup is time consuming and costly. However, the use of wire saws permits decreased effort later at the saw facility, and will result in decreased loss of stone. Wire saws are used chiefly on granite and limestone.

(4) Low level explosives, particularly black powder, are used in the quarrying of slate, marble, and mica schist.

(5) Jet piercing is used primarily with granite in the dimension stone industry. This technique is based on the use of high velocity jet flames to cut channels. It involves the combustion of fuel oil fed under pressure through a nozzle to attain jet flames of over 2600°C (5000°F). A stream of water joins the flame and the combined effect is spalling and disintegration of the rock into fragments which are blown out of the immediate zone.

(6) Splitting techniques of one sort or another seem to be used in the quarry on nearly all dimension stones. Splitting always requires the initial spaced drilling of holes in the stone, usually along a straight line, and following the "rift" of the stone if it is well defined. Simple wedges, or "plugs-and-feathers" are inserted in the holes and a workman then forces splitting by driving in the wedges with a sledge hammer. This technique appears crude, but with a skilled workman good cuts can be made.

After a large block of stone is freed, it is either hoisted on to a truck which drives from the floor of the quarry to the facility, or the block is removed from the quarry by means of a derrick, and then loaded on a truck.

Most dimension stone processing facilities are located at or close to the quarry. On occasion, centrally located facilities serve two or more quarries (facilities 3029, 3038, 3053, 3007, 3051). To a much lesser extent, one quarry can serve two or more processors (facilities 3304 and 3305). Also in a well defined, specialized producing area such as Barre, Vermont, two large quarriers, who are also stone processors, sell blocks and/or slabs to approximately 50 processors. However, the most common situation is that in which the processor has his own quarry. In this study, no situation was seen in which a quarry was operated without an accompanying processing facility.

In dimension stone processing, the first step is to saw the blocks into slabs. The initial sawing is accomplished using gang saws (large hack saws), wire saws, or occasionally, rotating diamond saws. All saw systems use considerable water for cooling and particle removal, but this water is usually recycled. Generally, the saw facility is operated at the same physical location as the finishing facility, and without any conscious demarkation or separation, but in a few cases the saw facility is either at a separate location (facilities 3034 and 3051), is not associated with any finishing operations (facilities 3008, 3010 and 5600), or is separately housed and operated but at the same location (facilities 3007 and 3001).

After the initial sawing of blocks to slabs of predetermined thickeness, finishing operations are initiated. The finishing operations used on the stone are varied and are a function of the properties of the stone itself, or are equally affected by characteristics of the end product. For example, after sawing, slate is hand split without further processing if used for structural stone, but is hand split, trimmed, and punched if processed into shingles, and it is hand split and trimmed if processed into flagstone. Slate is rarely polished, as the rough effect of hand splitting is desirable. Mica schist and sandstone are generally only sawed, since they are used primarily for external structural stone. Limestone cannot be polished, but it can be shaped, sculptured and machined for a variety of functional and/or primarily decorative purposes. Granite and marble are also multi-purposed stones and can take a high polish. Thus polishing equipment and supplies, and water usage, are important considerations for these two large categories of stone. Dolomitic limestone can be polished, but not to the same degree as granite or marble. Generally most of this stone is used primarily for internal or external structural pieces, veneer, sill stone, and rubble stone. A schematic flow sheet for dimension stone quarrying and processing is given in Figure 16.

Extremely large quantities of stone are quarried in the dimension stone industry, and yields of good quality stone are quite low and variable, from 15 percent to 65 percent and with 0.5 to 5.7 kkg of waste stone per kkg of product. The lowest yields are characteristic of the stones which are generally highly polished and therefore require the most perfection (granite and marble). Low yields (18 percent) also occur in slate due to large quantities of extraneous rock. Most of the losses occur at the quarry but some unavoidable losses also occur in the saw facilities and finishing facilities.

Some quarries require no water: mica schist, dolomitic limestone, slate and sandstone, (facilities 5600, 3017, 3018, 3053, 3039, 3040), as do some marble, travertine marble, and granite (facilities 3051, 3034, 3001, 3029). Ground or rain waters do accumulate in these quarries. Most limestone and some granite quarries do use water for sawing or channel cutting, (facilities 3038, 3304, 3305, 3306, 3007, 3008, 3009, 3010) therefore, ground and rain water is retained, and other sources of water may also be tapped for makeup. This water is continuously recycled into the quarry sump and is rarely discharged. Water is also used in wet drilling, but this quantity is small.

All saw facilities use water and the general practice is to recycle after settling most of the suspended solids. The raw waste load of TSS from saw facilities can be significant. The same is true of untreated effluents from finishing facilities. In many cases, the saw facilities and the finishing facilities are under the same roof, in which case the water effluents are combined.

In Table 11, water use data are presented for dimension stone facilities having reliable data available. Combined saw facility and finishing facility raw water effluents vary from 4,340 to 43,400 l/kkg of product (1,040 to 10,400 gal/ton). Water usage varies due to varying stone processes, water availability, and facility attitudes on water usage.

The quality of intake water used in dimension stone processing appears to be immaterial. For the most part, river, creek, well, abandoned quarry, or lake water is used without pretreatment. Occasionally pretreatment in the form of prior elementary screening or filtration is performed (facilities 3018, 3051), and in only two instances is city water used (facility 3007, 3029) as part of the makeup water.

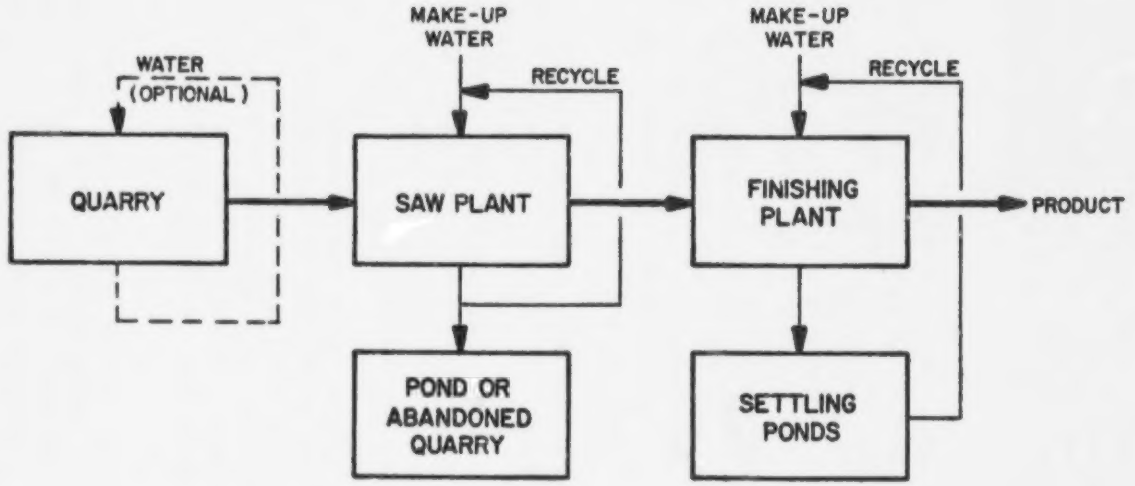

WATER
(OPTIONAL)
QUARRY
MAKE-UP
WATER
RECYCLE
SAW PLANT
POND OR
ABANDONED
QUARRY
MAKE-UP
WATER
RECYCLE
FINISHING
PLANT
SETTLING
PONDS
PRODUCT

FIGURE 16
DIMENSION STONE MINING AND PROCESSING

TABLE 11
Dimension Stone Water Use

Stone and Plant	Makeup Water 1/kkg of stone processed (gal/ton)	Water Use, 1/kkg of stone processed (gal/1000 lb) Saw Plant	Finish Plant	Combined
Mica Schist				
5600	20 (5)	4,460	none	4,460
Slate				
3053	450 (110)	unknown	unknown	4,550
Dolomitic Limestone				
3039	1,250 (300)	unknown	unknown	unknown
3040	13,000 (3100)	unknown	unknown	13,000
Limestone				
3007	540 (130)	16,600	1,600	18,200
3009	unknown	unknown	unknown	6,030
3010*	unknown	9,800		9,800
Granite				
3001	unknown	7,350	7,360	14,700
3029	840 (200)	unknown	unknown	3,900
3038	1,600 (390)	unknown	unknown	43,400
Marble				
3051	100,000 (24,000)	100,000	unknown	unknown
3304	590 (140)	unknown	unknown	5,940
3305	unknown	unknown	unknown	39,800**
3306	1,300 (300)	unknown	unknown	6,500

* No finishing plant
** Primarily a saw plant which ships slabs to 3304 for finishing.

CRUSHED STONE (SIC 1422, 1423, 1429)

Three basic methods of extraction are practiced: (1) removal of raw material from an open face quarry; (2) removal of raw material from an underground mine (approximately 5 percent of total crushed stone production); and (3) shell dredging, mainly from coastal waterways (approximately 1 percent of total crushed stone production). Once the raw material is extracted, the methods of processing are similar, consisting of crushing, screening, washing, sizing, and stockpiling. For approximately 0.2 percent of total crushed stone production, flotation techniques are employed to obtain a calcite ($CaCO_3$) product. The industry was divided into the following subcategories:

(1) Dry process
(2) Wet process
(3) Flotation process
(4) Shell dredging

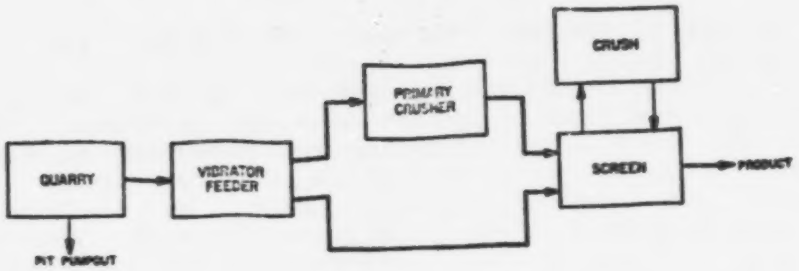
These facilities contacted are located in 38 states in all areas of the nation representing various levels of yearly production and facility age. Production figures range from 36,000 - 1,180,000 kkg/yr (40,000-1,300,000 tons/yr) and facility ages vary from less than one year to over 150 years old. Figure 17 shows the different methods of processing.

DRY PROCESS

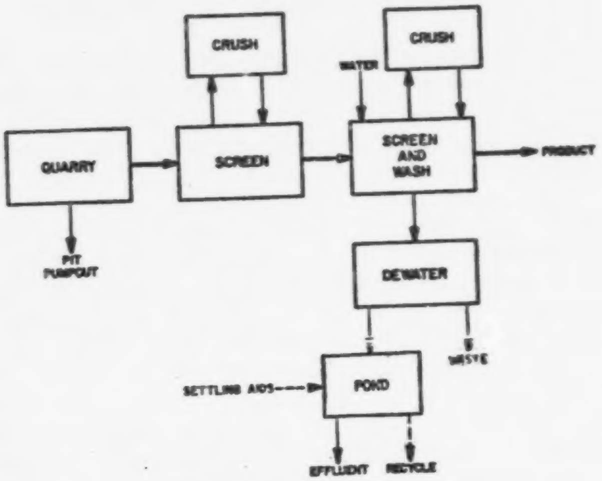
Most crushed stone is mined from quarries. After removal of the overburden, drilling and blasting techniques are employed to loosen the raw material. The resulting quarry is characterized by steep, almost vertical walls, and may be several hundred meters deep. Excavation is normally done on a number of horizontal levels, termed benches, located at various depths. In most cases, front-end loaders and/or power shovels are utilized to load the raw material into trucks which in turn transport it to the processing facility. In some cases, however, the raw material is moved to the facility by a conveyor belt system perhaps preceded by a primary crusher. Another variation is the use of portable processing facilities which can be situated near the blasting site, on one of the quarry benches or on the floor of the quarry. In this situation, the finished product is trucked from the quarry to the stockpile area. Specific methods vary with the nature and location of the deposit.

No distinction is made between permanent facilities and portable facilities since the individual operations therein are basically identical. At the processing facility, the

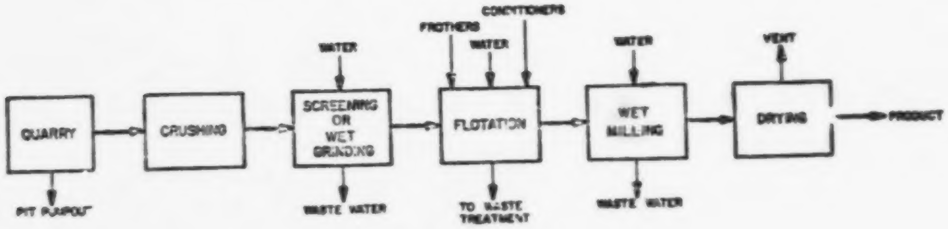
FIGURE 17


QUARRY
PIT PUMPOUT
VIBRATOR FEEDER
PRIMARY CRUSHER
CRUSH
SCREEN
PRODUCT

CRUSHED STONE MINING AND PROCESSING
(DRY)


QUARRY
PIT PUMPOUT
SCREEN
CRUSH
WATER
CRUSH
SCREEN AND WASH
PRODUCT
DEWATER
WASTE
SETTLING AIDS
POND
EFFLUENT
RECYCLE

CRUSHED STONE MINING AND PROCESSING
(WET)


QUARRY
PIT PUMPOUT
CRUSHING
WATER
SCREENING OR WET GRINDING
WASTE WATER
FROTHERS
CONDITIONERS
WATER
FLOTATION
TO WASTE TREATMENT
WATER
WET MILLING
WASTE WATER
VENT
DRYING
PRODUCT

CRUSHED STONE MINING AND PROCESSING
(FLOTATION PROCESS)

raw material passes through screening and crushing operations prior to the final sizing and stockpiling. Customer demands for various product grades determine the number and position of the screens and crushers. No process water is used in the crushing and screening of dry process crushed stone. Many operators dewater their quarries because of ground water, rain, or surface runoff. Approximately half of the quarries studied dewater their quarries either on an intermittent or continual basis. Incidental water uses include non-contact cooling water for cooling crusher bearings and water used for dust suppression, which is adsorbed onto the product and does not result in a discharge.

CRUSHED STONE, WET PROCESS

Excavation and transportation of crushed stone for wet processing are identical to those for dry processing. Wet processing is the same as dry processing with the exception that water is added to the system for washing the stone. This is normally done by adding spray bars to the final screening operation after crushing. In many cases, not all of the product is washed, and a separate washing facility or tower is incorporated which receives only the material to be washed. This separate system will normally only include a set of screens for sizing which are equipped with spray bars. In the portable processing facility, a portable wash facility can also be incorporated to satisfy the demands for a washed material. At facility 5662, the finished product from the dry facility is fed into a separate unit consisting of a logwasher and screens equipped with spray bars. Incidental water is used for non-contact cooling and/or dust suppression. Use varies widely as the following shows:

Facility	Water Use l/kkg of product (gal/1000 lb) Non-contact Cooling	Dust Suppression
1001	None	None
1002	None	None
1003	None	None
1004	None	None
1021	None	500
1022	8	None
1023	Unknown	16
1039	None	Unknown
1040	None	13
1212	None	None
1213	None	None
1215	290	8
1221	None	None
1974	17	60
5640	None	None

Water necessary for the washing operations is drawn from any one or combination of the following sources: quarries, wells, rivers, company owned ponds, and settling ponds. There is no set quantity of water necessary for washing crushed stone as the amount required is dependent upon the deposit from which the raw material is extracted. A deposit associated with a higher percentage of fine material will require a larger volume of water to remove impurities than one with a lower percentage of fines. A second factor affecting the amount of washwater is the degree of crushing involved. The amount of undesirable fines increases with the number of crushing operations, and consequently a greater volume of water is necessary to wash the finer grades of material.

Facility	Washwater Percent of washed material	l/kkg of product (gal/ton)
5663	8	40 (10)
5640	15	670 (160)
1439	40	1050 (250)
1219	50	1250 (300)
1004	100	330 (80)
1003	100	690 (165)

Less than 10 percent of all crushed limestone operators dry their product. Approximately 5 percent of these operators employ a wet scrubber in conjunction with the dryer as a means of air pollution control. Facility 1217 uses a rotary dryer for approximately 30-40 percent of the total production time. The wet scrubber associated with this dryer utilizes water at the rate of 2,600 l/kkg of dried product (690 gal/ton).

The quantity of raw waste varies as shown by the tabulation as follows:

Facility	Raw Waste Load, kg/kkg of Product	Facility	Raw Waste Load, kg/kkg of Product
1001	40	1212	270
1002	50	1213	30
1003	40	1215	10
1004	150	1221	130
1021	80	1974	22
1023	20	5640	10
1039	20	5664	180

CRUSHED STONE, FLOTATION PROCESS

Marble or other carbonaceous rock is transported from the quarry to the processing facility where it is crushed, screened or wet milled and fed to flotation cells. Impurities are removed in the overflow and the product is collected from the underflow. It is further wet milled to achieve a more uniform particle size, dried, and shipped.

The water use for the three facilities is outlined as follows. There are considerable variations in process and mine pumpout waters.

	l/kkg of product (gal/ton)		
Type	1975	3069	1021
process	151,000 (36,000)	4,900 (1,170)	2,570 (610)
cooling	22,700 (5,400)	850 (200)	-----
dust control	1,510 (360)	1,400 (335)	
boiler	------	6,600 (1,580)	------
mine pumpout	unknown	none	16,000 (3,800)

Facility 1975 also employs some of this process water to wash other materials.

Process raw wastes consist of clays and fines separated during the initial washing operations and iron minerals, silicates, mica, and graphite separated by flotation.

waste	kg/kkg of product (lb/1000 lb) 1975	 3069
clays and fines	1,000	unknown
flotation wastes (solids)	50-100	50-100

In addition to the above, the flotation reagents added (organic amines, fatty acids and pine oils) are also wasted. The quantities of these materials are estimated to range from 0.1 to 1.0 kg/kkg of material.

SHELL DREDGING

Shell dredging is the hydraulic mining of semi-fossil oyster and clam shells which are buried in alluvial estuarine sediments. Extraction is carried out using floating, hydraulic suction dredges which operate in open bays and sounds, usually several miles from shore. This activity is conducted along the coastal Gulf of Mexico and to a lesser extent along the Atlantic coast. Shell dredges are self-contained and support an average crew of 12 men working 12 hours/day in two shifts.

All processing is done on board the dredge and consists of washing and screening the shells before loading them on tow-barges for transport to shore. Shell is a major source of calcium carbonate along the Gulf Coast States and is used for construction aggregate and Portland cement manufacturing. Shell dredging and on-board processing is regulated under section 404 of the Act, Permits for Dredged or Fill Material.

CONSTRUCTION SAND AND GRAVEL (SIC 1442)

Three basic methods of sand and gravel extraction are practiced: (1) dry pit mining above the water table; (2) wet pit mining by a dragline or barge-mounted dredging equipment both above and below the water table; and (3) dredging from public waterways, including lakes, rivers, and estuaries. Once the raw material is extracted, the methods of processing are similar for all cases, typically consisting of sand and gravel separation, screening, crushing, sizing, and stockpiling. The industry was divided into dry process, wet process and dredging with on-land processing. The facilities contacted are located in 22 states in all regions of the nation representing production levels from 10,800 kkg/yr (12,000 tons/yr) to over 1,800,000 kkg/yr (2,000,000 tons/yr). Facility ages varied from less than a year old to more than 50 years old. Figure 18 shows the different methods of processing.

DRY PROCESS

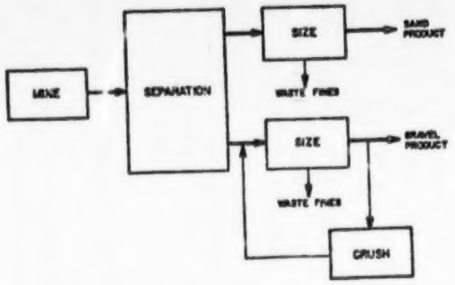
After removal of the overburden, the raw material is extracted via front-end loader, power shovel or scraper and conveyed to the processing unit by conveyor belts or trucks. At the processing facility, the sand is separated from the gravel via inclined vibrating screens. The larger sizes are used as product or crushed and re-sized. The degree of crushing and sizing is highly dependent on the needs of the user.

No water is used in the dry processing of sand and gravel. Mine pumpout may occur during periods of rainfall or, in the cases of portable or intermittent operations, prior to the initial start-up. Most pumpout occurs when the water level reaches a predetermined height in a pit or low-area sump. Incidental water uses may include non-contact cooling water for crusher bearings and water for dust suppression. This latter water either remains with the product or evaporates.

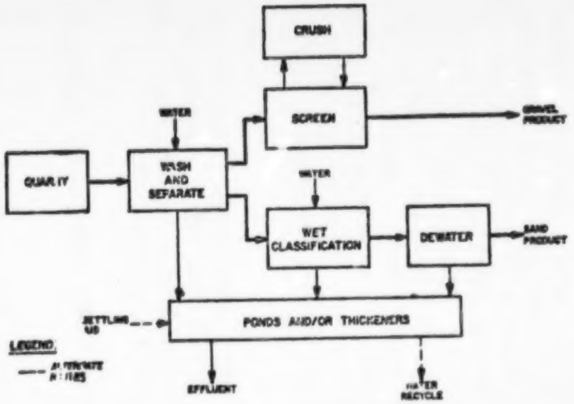
WET PROCESS

Sand and gravel operations requiring extraction from a wet pit or quarry typically use a dragline or a hydraulic dredge to excavate the material. The hydraulic dredge conveys the raw material as a wet slurry to the processing facility. After removal of the overburden, the raw material from a dry pit or quarry is extracted via front-end loader, power shovel or scraper, and conveyed to the processing facility on conveyor belts or in haul trucks.

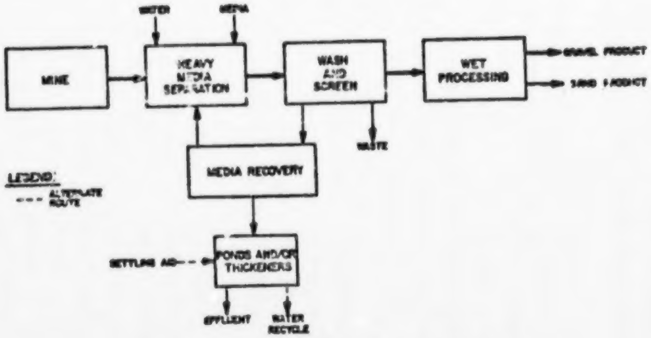
FIGURE 18


MINE
SEPARATION
SIZE
SAND PRODUCT
WASTE FINES
SIZE
GRAVEL PRODUCT
WASTE FINES
CRUSH

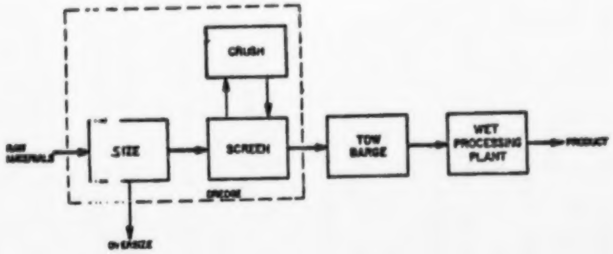
SAND AND GRAVEL MINING AND PROCESSING
(DRY)


CRUSH
WATER
SCREEN
GRAVEL PRODUCT
QUARRY
WASH AND SEPARATE
WATER
WET CLASSIFICATION
DEWATER
SAND PRODUCT
SETTLING AID
PONDS AND/OR THICKENERS
LEGEND:
ALTERNATE ROUTE
EFFLUENT
WATER RECYCLE

SAND AND GRAVEL MINING AND PROCESSING
(WET)


WATER
MEDIA
MINE
HEAVY MEDIA SEPARATION
WASH AND SCREEN
WET PROCESSING
GRAVEL PRODUCT
SAND PRODUCT
WASTE
MEDIA RECOVERY
LEGEND:
ALTERNATE ROUTE
SETTLING AID
PONDS AND/OR THICKENERS
EFFLUENT
WATER RECYCLE

SAND AND GRAVEL MINING AND PROCESSING
(HMS)


CRUSH
RAW MATERIALS
SIZE
SCREEN
DREDGE
TOW BARGE
WET PROCESSING PLANT
PRODUCT
OVERSIZE

SAND AND GRAVEL MINING AND PROCESSING
(DREDGING WITH ON-LAND PROCESSING)

Water in this subcategory is used to wash the clay or other impurities from the sand and gravel. State, local, and Federal specifications for construction aggregates require the removal of clay fines and other impurities. The sand and gravel deposits surveyed during this study ranged from 5 to 30 percent clay content. Facility processing includes washing, screening, and otherwise classifying to size, crushing of oversize, and the removal of impurities. Impurities which are soluble or suspendable in water (e.g., clays) generally are washed out satisfactorily. A typical wet processing facility would consist of the following elements:

(1) A hopper, or equivalent, receives material transported from the deposit. Generally, this hopper will be covered with a "grizzly" of parallel bars to screen out rocks too large to be handled by the facility.

(2) A scalping screen separates oversize material from the smaller marketable sizes.

(3) The material passing through the scalping screen is fed to a battery of screens, either vibrating or revolving, the number, size, and arrangement of which will depend on the number of sizes to be made. Water from sprays is applied throughout the screening operation.

(4) From these screens the different sizes of gravel are discharged into bins or onto conveyors to stockpiles, or in some cases, to crushers and other screens for further processing. The sand fraction passes to classifying and dewatering equipment and from there to bins and stockpiles. Classifiers are troughs in which sand particles will settle at different points according to their weight. The largest and heaviest particles will settle first. The finest will overflow the classifier and be wasted. Screens are used to separate the sand from the gravel and to size sand larger than 20 mesh. Finer sizes of sand are produced by classification equipment.

A small number of facilities must remove deleterious particles occurring in the deposit prior to washing and screening. Particles considered undesirable are soft fragments, thin and friable particles, shale, argillaceous sandstones and limes, porous and unsound cherts, coated particles, coal, lignite and other low density impurities. Heavy-media separation (sink-float) is used for the separation of materials based on differing specific gravities. The process consists of floating the lightweight material from a heavy "liquid" which is formed by suspension of finely ground heavy ferromagnetic materials such as magnetite and/or ferrosilicon in water. The "floated" impurities and the "sink" product (sand and gravel) are passed over separate screens where the magnetite and/or ferrosilicon are removed by magnetic separation and recycled. The impurities are usually disposed of in nearby pits while the product is transported to the facility for routine washing and sizing.

Process water includes water used to separate, wash, and classify sand and gravel. Incidental water is used for non-contact cooling and dust suppression. Water used for sand and gravel separation enters a rotary scrubber or is sprayed via spray bars onto a vibratory inclined screen to separate the sand and the clay from the gravel. The sand slurry is further processed via hydraulic classification where additional water is usually added. As the source of the raw material constantly changes, so does the raw waste load and the amount of water required to remove these wastes. The following tabulates process water use at selected facilities:

Facility	l/kkg of product	gal/ton
1006	2500	600
1012	9400	2250
1055	3400	820
1391	1430	340
5630	1460	350
5656	750	180
5666	7400	1800
5681	2000	480

Facilities 1012 and 5666 have markedly higher hydraulic loads than the others because they use hydraulic suction line dredges.

Raw wastes consist of clays, fine mesh sands (usually less than 150 mesh), and other impurities. Oversize material is usually crushed to size and processed. The amounts of these wastes are variable, depending on the nature of the raw material (i.e., percent of clay content) and degree of processing at the facility. Facility 1981, using heavy-media separation prior to wet processing, floats out 150 kg/kkg of the total raw material fed to the facility. The following lists the rate of raw waste generation at several other facilities:

Facility	kg/kkg of raw material (lb/1000 lb)
1006	140
1007	480
1055	50
1056	250
1391	80
3091	110

DREDGING WITH ON-LAND PROCESSING

The raw material is extracted from rivers and estuaries using a floating, movable dredge which excavates the bottom sand and gravel deposit by one of the following general methods: a suction dredge with or without cutter-heads, a clamshell bucket, or a bucket ladder dredge. After the sand and gravel is brought on-board, primary sizing and/or crushing is accomplished with vibrating or rotary screens, and cone or gyratory crushers with oversize boulders being returned to the water. The general practice in this subcategory is to load a tow-barge which is tied alongside the dredge. The barge is transported to a land-based processing facility where the material is processed similar to that described for wet processing of sand and gravel. The degree of sand and gravel processing on-board the dredge is dependent on the nature of the deposit and customer demands for aggregate. Dredges 1010, 1052 and 1051 extract the raw material via clamshell or bucket ladder, remove oversize boulders, size, and primary crush on-board. Dredges 1046 and 1048 extract via clamshell, but have no on-board crushing or sizing. The extracted material for all the above-mentioned dredges is predominantly gravel. This gravel must undergo numerous crushing and sizing steps on land to manufacture a sand product which is absent in the deposit.

Dredges 1011 and 1009 excavate the deposit with cutter-head suction line dredges since the deposit is dominated by sand and small gravel. Dredge 1011 pumps all the raw material to an on-land processing facility. Dredge 1009, due to the lack of demand for sand at its location, separates the sand and gravel on-board the dredge with the sand fraction being returned to the river. The gravel is loaded onto tow barges and transported to a land facility where it is wet processed. The dredges in this subcategory vary widely in capital investment and size. Dredge 1046 consists of a floating power shovel powered by a diesel engine which digs the deposit and loads it onto a tow barge. A shovel operator and a few deck hands are on-board during the excavation which is usually only an eight-hour shift. Dredge 1009 is much larger and sophisticated since it requires partial on-board separation of sand and gravel. This dredge is manned by a twelve-man crew per shift, with complete crew live-in quarters and attendant facilities. This dredge operates 24 hours/day.

Water use at the land facilities is similar to wet processing subcategory facilities. Process water is used to separate, wash, and classify sand and gravel. Incidental water includes non-contact cooling and dust suppression. Water used for dust suppression averages 15 l/kkg (3.8 gal/ton) of gravel processed. Water use at the dredge depends on the excavation method. Some clamshell and ladder bucket dredges do not use process water because there is no on-board washing. Suction line dredges bring up the raw material as a slurry, remove the aggregate, and return the water to the river. Water use at land facilities is variable depending on the raw material and degree of processing as shown below:

Facility	l/kkg of feed	gal/ton
1009	2200	530
1010	1400	340
1046	1000	240
1048	3440	825
1051	1300	320
1052	1500	360

Raw wastes consist of oversize or unusable material which is discarded at the dredge and undersize waste fines (-150 mesh) which are handled at the land-based processing facility. The amount of waste material is variable depending on the deposit and degree of processing. On the average, 25 percent of the dredged material is returned to the river. Waste fines at land facilities average 10 percent. The following tabulates waste loads at selected operations:

Dredge	At Dredge kg/kkg of feed (lb/1000 lb)	At Land Facility kg/kkg of feed (lb/1000 lb)
1009	460	100
1010	none	400
1011	none	150
1046	none	110
1048	none	120
1051	250	60
1052	180	120

The clay content of dredged sand and gravel, usually averaging less than 5 percent, is less than that of land deposits due to the natural rinsing action of the river. Unsaleable sand fines resulting from crushing of gravel to produce a manufactured sand represent the major waste load at the land facilities.

DREDGING WITH ON-BOARD PROCESSING

The raw material is extracted from rivers and estuaries using a floating, movable dredge which excavates the bottom sand and gravel deposit by one of the following general methods: a suction dredge with or without cutter-heads, a clamshell bucket, or a bucket ladder dredge. After the sand and gravel is brought on-board, complete material processing similar to that described in the wet process subcategory, occurs prior to the loading of tow-barges with the sized sand and gravel. Typical on-board processing includes: screening, crushing of oversize, washing, sand classification with hydraulic classifying tanks, gravel sizing, and product loading. Numerous variations to this process are demonstrated by the dredges visited. Dredges 1017 and 1247 use a rotary scrubber to separate the sand and gravel which has been excavated from land pits, hauled to the lagoon where the dredge floats, and fed into a hopper ahead of the rotary scrubber. Dredge 1008 excavates with a revolving cutter head suction line in a deposit dominated by sand. The sand is separated from the gravel and deposited into the river channel without processing. Only the gravel is washed, sized, and loaded for product as there is little demand for sand at this location. Dredge 1050 employs bucket ladders, rough separates sand from gravel, sizes the gravel crushing the oversize, and removes deleterious materials from the gravel by employing heavy media separation (HMS). HMS media (magnetite/ferrous silica) is recovered, and returned to the process. Float waste is discharged into the river. Dredge 1049, a slack-line bucket ladder dredge normally works a river channel. However, during certain periods of the year it moves into a lagoon where water monitors "knock down" a shoreline sand and gravel deposit into the lagoon in front of the buckets. All of the dredges pump river water for washing and sand classification. Periods of operation are widespread for the dredges visited. Dredge 1008 operates all year, 24 hours per day (two-12 hour shifts). Dredge 1049 operates two 8 hour shifts for 10 months. Dredging for sand and gravel in navigable waters is regulated under section 404 of the Act.

INDUSTRIAL SAND (SIC 1446)

The three basic methods of extraction are:

(1) Mining of sand from open pits;
(2) Mining of sandstone from quarries; and
(3) hydraulic dredging from wet pits.

Once the raw material is extracted, the basic operations involved in the production of all types of industrial sand are classification and removal of impurities. The amount of impurities in the raw material is dependent upon the percentage of silica in the deposit. The subsequent level of technology involved in the removal of these impurities depends on the desired grade of product. Glass sand, for example, requires a higher degree of purity than does foundry sand. The industry was divided into the following subcategories:

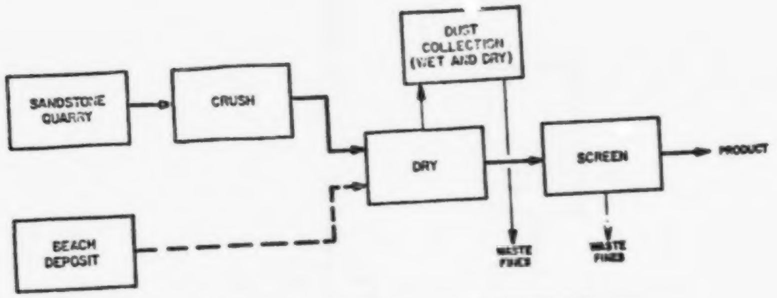
(1) Dry Process
(2) Wet Process
(3) Flotation Process
(4) Acid Leaching Process

Two of the wet process facilities also use flotation on a small percentage of their finished product, and are included in the flotation process subcategory. Production, in the facilities contacted, ranges from 32,600 - 1,360,000 kkg/yr (36,000 - 1,500,000 tons/yr) and facility ages vary from less than one year to 60 years. Figure 19 shows the different types of processing.

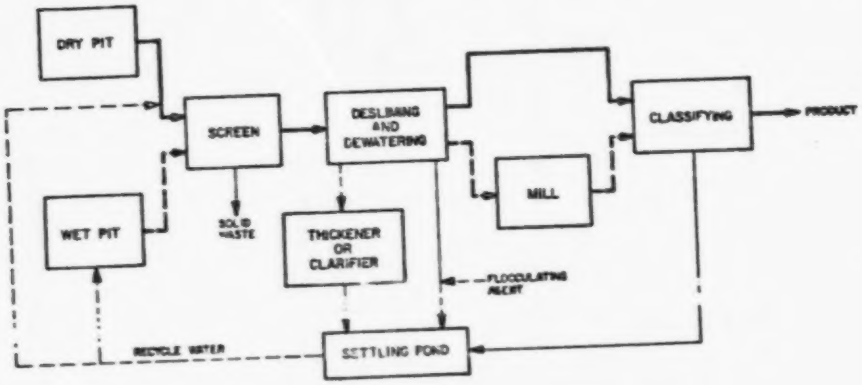
DRY PROCESS

Approximately 10 percent of the industrial sand operations fall into this subcategory, characterized by the absence of process water for sand classification and beneficiation. Typically, dry processing of industrial sand is limited to scalping or screening of sand grains which have been extracted from a beach deposit or crushed from sandstone. Facilities 1106 and 1107 mine a beach sand which has been classified into grain sizes by natural wind action. Sand, of a specific grain size, is trucked to the facility where it is dried and cooled, and coarse grain is scalped and stored. Processing of beach sand which is excavated at differing distances from the shoreline, enables the facility to process a number of grain sizes which can be blended to meet customer specifications.

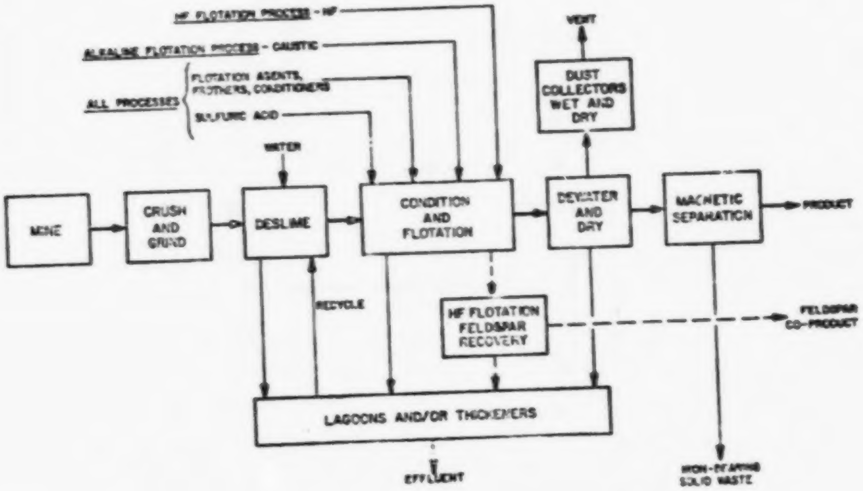
FIGURE 19


SANDSTONE QUARRY
CRUSH
BEACH DEPOSIT
DUST COLLECTION (WET AND DRY)
DRY
SCREEN
PRODUCT
WASTE FINES
WASTE FINES
LEGEND:
ALTERNATE ROUTE

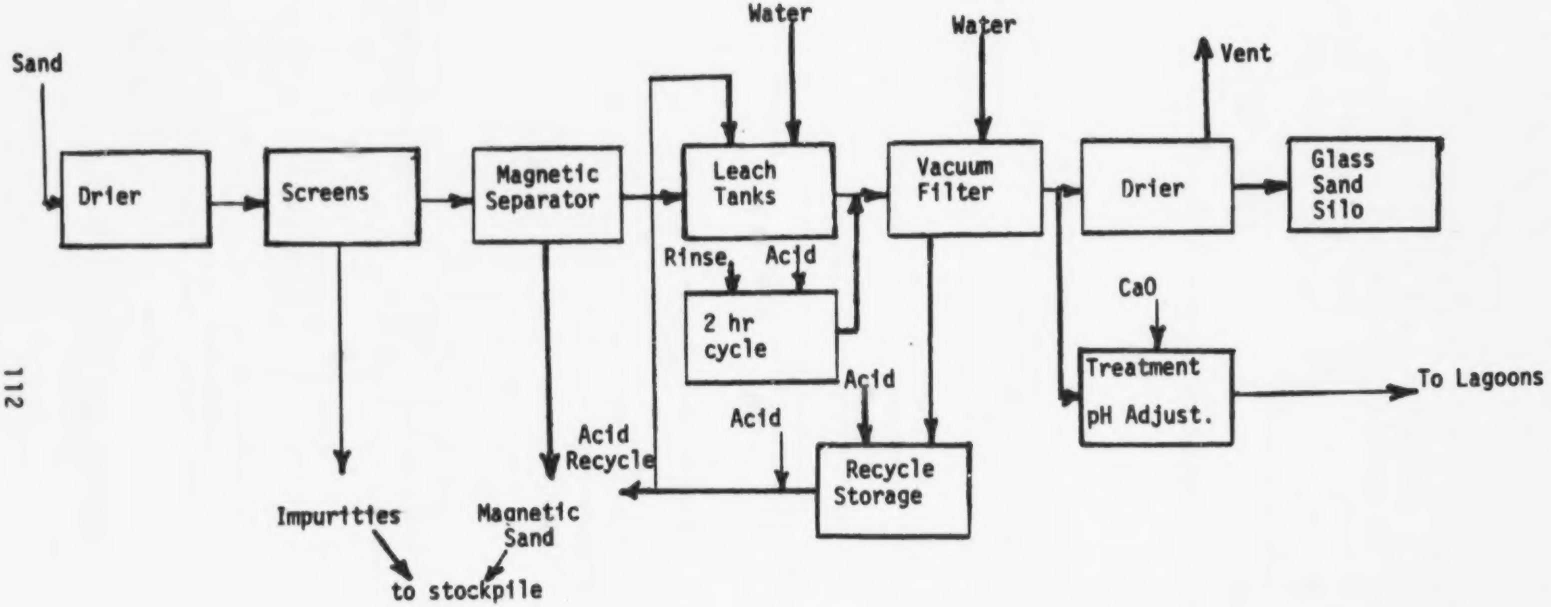
INDUSTRIAL SAND MINING AND PROCESSING (DRY)


DRY PIT
WET PIT
SCREEN
SOLID WASTE
DESLIMING AND DEWATERING
THICKENER OR CLARIFIER
MILL
CLASSIFYING
PRODUCT
FLOCCULATING AGENT
SETTLING POND
RECYCLE WATER

INDUSTRIAL SAND MINING AND PROCESSING (WET)


HF FLOTATION PROCESS - HF
ALKALINE FLOTATION PROCESS - CAUSTIC
ALL PROCESSES
FLOTATION AGENTS, FROTHERS, CONDITIONERS
SULFURIC ACID
WATER
MINE
CRUSH AND GRIND
DESLIME
RECYCLE
CONDITION AND FLOTATION
HF FLOTATION FELDSPAR RECOVERY
VENT
DUST COLLECTORS WET AND DRY
DEWATER AND DRY
MAGNETIC SEPARATION
PRODUCT
FELDSPAR CO-PRODUCT
LAGOONS AND/OR THICKENERS
EFFLUENT
IRON-BEARING SOLID WASTE

INDUSTRIAL SAND MINING AND PROCESSING (FLOTATION PROCESSES)


Sand
Drier
Screens
Magnetic Separator
Water
Leach Tanks
Rinse
Acid
2 hr cycle
Water
Vacuum Filter
Acid
Acid
Recycle Storage
Acid Recycle
Vent
Drier
Glass Sand Silo
CaO
Treatment
pH Adjust.
To Lagoons
Impurities
Magnetic Sand
to stockpile

INDUSTRIAL SAND - ACID LEACHING PROCESS

Facilities 1109 and 1110 quarry a sandstone, crush, dry, and screen the sand prior to sale as a foundry sand. Facility 1108 is able to crush, dry, and screen a sandstone of high enough purity to be used for glassmaking. Most of the facilities use a dust collection system at the dryer to meet air pollution requirements. Dust collection systems are both dry (cyclones and baghouses in facilities 1106, 1109 and 1110) or wet (wet scrubbers in facilities 1107 and 1108).

No water is used to wash and classify sand in this subcategory. Facilities 1108 and 1107 use a wet dust collection system at the dryer. Water flows for these two wet scrubbers are shown below:

Wet Scrubber Water Use	Facility 1107	Facility 1108
total flow, l/min (gal/min)	9460 (2500)	115 (30)
amount recirculated, l/min (gal/min)	9390 (2480)	0
amount discharged l/min (gal/min)	0	115 (30)
amount makeup, l/min (gal/min)	76 (20)	115 (30)

Although the five facilities surveyed in this subcategory did not use non-contact cooling water, it may be used in other facilities.

WET PROCESS

Mining methods vary with the facilities in this subcategory. Facility 3066 scoops the sand off the beach, while facility 1989 hydraulically mines the raw material from an open pit. Facility 1019 mines sandstone from a quarry. At this facility water is used as the transport medium and also for processing. Facility 1019 dry crushes the raw material prior to adding water. An initial screening is usually employed by most facilities consisting of a system of scalpers, trommels and/or classifiers where extraneous rocks, wood, clays, and other matter is removed. Facility 1102 wet mills the sand to produce a finer grade of material. At all facilities water is filtered off, and the sand is then dried, cooled, and screened. Facility 3066 magnetically separates iron from the dried product. The finished product is then stored to await shipment. Facility 3066 mines a feldspathic sand. This, however, does not require any different method of processing.

There is no predetermined quantity of water necessary for washing industrial sands as the amount required is dependent upon the impurities in the deposit. Typical amounts of process water range from 170 to 12,000 l/kkg product.

FLOTATION PROCESS

Within this subcategory, three flotation techniques are used:

(1) Acid flotation to effect removal of iron oxide and ilmenite impurities,
(2) Alkaline flotation to remove aluminate bearing materials, and
(3) Hydrofluoric acid flotation for removal of feldspar.

In acid flotation, sand or quartzite is crushed, and milled into a fine material which is washed to separate adhering clay-like materials. The washed sand is slurried with water and conveyed to the flotation cells. Sulfuric acid, frothers and conditioning agents are added and the silica is separated from iron-bearing impurities. The reagents include sulfonated oils, terpenes and heavy alcohols in amounts of up to 0.5 kg/kkg of product. In the flotation cells, the silica is depressed and sinks, and the iron-bearing impurities are "floated" away. The purified silica is recovered, dried and stockpiled. The overflow containing the impurities is sent to the wastewater treatment system.

In alkaline flotation, the process is very similar to that described above with the following difference: before the slurried, washed sand is fed to the flotation cell, it is pretreated with acid. In the cell, it is treated with alkaline solution (aqueous caustic, soda ash or sodium silicate), frothers and conditioners. The pH is generally maintained at about 8.5 (versus about 2 in acid flotation). Otherwise, the process is the same as for acid flotation. Materials removed or "floated" by alkaline flotation are aluminates and zirconates.

In hydrofluoric acid flotation operations, after the raw sand has been freed of clays by various washing operations, it is subjected to a preliminary acid flotation of the type described above. The underflow from this step is then fed to a second flotation circuit in which hydrofluoric acid and terpene oils are added along with conditioning agents to float feldspar. The underflow from this second flotation operation is collected, dewatered and dried. The overflow, containing feldspar, is generally sent to the waste water treatment system.

Facility water uses are shown as follows. Most of the water is recycled. The unrecycled water for the alkaline and HF processes is used for the flotation steps. For the acid flotation at least two facilities (1101 and 1980) have achieved total recycle. Facility 1019 impounds process discharge as wet sludge. Facility 1103 returns process waste water to the same wet pit where the raw material is extracted, adding make-up water for losses due to evaporation.

	l/kkg of product					
Facility	**1101**	**1019**	**1980**	**1103**	**5691**	**5980**
Process Recycle	25,400	2,580	23,200	27,300	8,400	24,200
Process Discharge	none	none*	none	6,830	5,250	914
Scrubber (recycle)	none	none	50 (10)	none	none	none
Total	25,400	2,930	23,250	34,130	13,650	25,700

* As impounded wet sludge

Process raw wastes from all three flotation processes consist of muds separated in the initial washing operations, iron oxides separated magnetically and materials separated by flotation. The amounts of wastes are given as follows.

		Amount kg/kkg of raw material (lb/1000 lb)					
Waste	**Source**	**1101**	**1019**	**1980**	**1103**	**5691**	**5980**
Clays	Washing	10	530	48	36	3	165
Flotation tailings	Flotation	50	20	60	140	17	135
Iron oxides	Magnetic separation	none	none	12	none	none	34
Acid & flotation agents*	Flotation				0.055		0.3
Fluorides (as HF)	HF Flotation tailings	none	none	none	none	none	0.45

* Generally flotation agents consist of oils and petroleum sulfonates and in some cases, minor amounts of amines.

ACID LEACHING PROCESS

The acid leaching or feldspathic sand process is principally designed for the removal of iron to the levels acceptable to the glass industry. This process consists of initial drying, screening for removal of oversize particles, initial iron removal using five roll high intensity magnetic separators, followed by wet process acid leaching in special vessels for complete inundation in a strong hydrochloric acid or sulfuric acid solution. This is followed by processing over a vacuum filter for leach solution recovery, washing, dewatering, and then final drying in a rotary parallel flow dryer before storage and delivery to the customers.

The water use at facility 3215 is 13.2 liters/kkg (55 gal/ton) of product. The raw waste load of the wastewaters from this plant's acid leaching process is given below. The pH range from 1-2.

	kg/kkg	(lb/ton) of product
iron (as Fe_2O_3)	1.25	(2.5)
TDS	8.01	(16.0)
R_2O_3	1.96	(3.92)
Al_2O_3	0.710	(1.42)

GYPSUM

Although some underground mining of gypsum is practiced, quarrying is the dominant method of extraction. The general procedure for gypsum processing includes crushing, screening, and processing. An air-swept roller mill is most commonly used. Two facilities use heavy media separation for beneficiation of a low-grade gypsum ore prior to processing. Ninety percent of all gypsum ore is calcined into gypsum products including wall board, lath, building plasters and tile. The remaining 10 percent is used as land plaster for agricultural purposes and in cement. The manufacture of gypsum products is not covered in this report. The cutoff out point between gypsum processing and gypsum products is just prior to calcination.

Thirty-six companies mined crude gypsum at 65 mines in 21 states in 1972. Five major companies operate 32 mines from which over 75 percent of the total crude gypsum is produced. Based on 5 facility visits and 36 facility contacts (63% of the total), the industry was divided into the following subcategories:

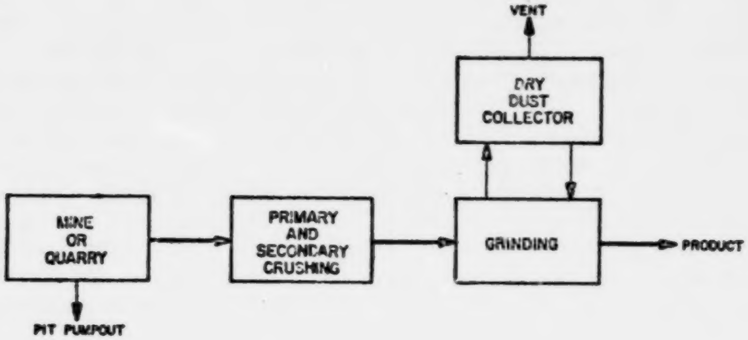
(1) Dry
(2) Wet scrubbing
(3) Heavy media separation

The facilities studied were in all regions of the nation representing various levels of yearly production and age. The different methods of processing are shown in Figure 20.

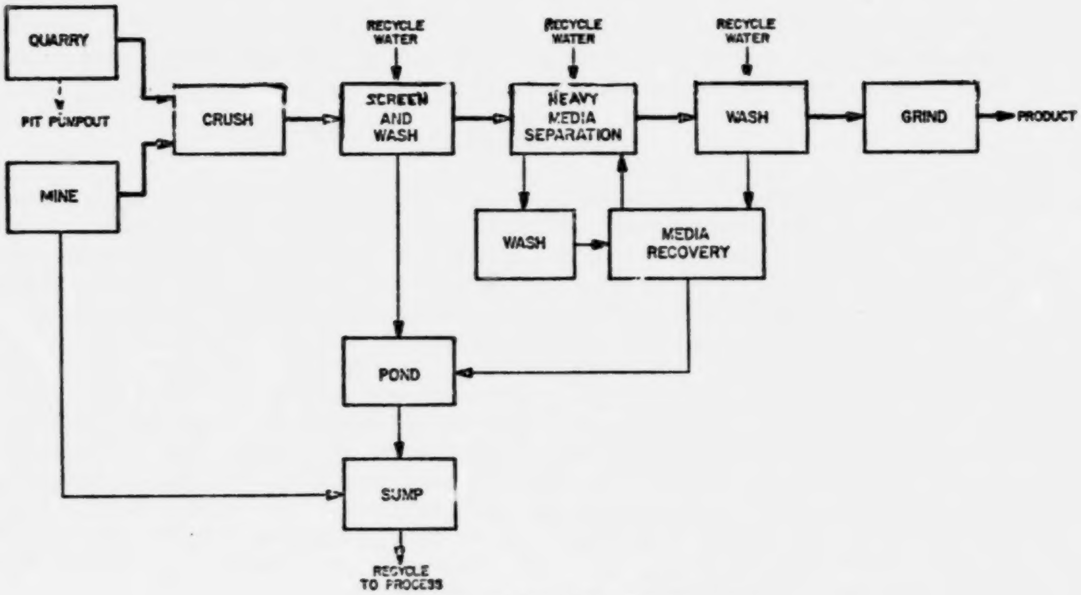
DRY PROCESS

Underground mining is carried out in most mines by the room-and-pillar method, using trackless mining equipment. In quarrying, stripping is accomplished both with draglines and tractors. Quarry drilling methods are adapted to meet local conditions. Low-density, slow-speed explosives are employed in blasting. Loading is commonly done with diesel or electric shovels. Transportation may be by truck or rail from quarry to facility. Primary crushing is done at most quarries using gyratory and jaw crushers and impact mills. Secondary crushing is usually accomplished by gyratory units, and final crushing almost exclusively by hammermills. The common unit for grinding raw gypsum is the air-swept roller mill. Ground gypsum is usually termed "land plaster" since in this form it is sacked or sold as bulk for agricultural purposes.

FIGURE 20


VENT
DRY DUST COLLECTOR
MINE OR QUARRY
PRIMARY AND SECONDARY CRUSHING
GRINDING
PRODUCT
PIT PUMPOUT

GYPSUM MINING AND PROCESSING
(DRY)


QUARRY
PIT PUMPOUT
MINE
CRUSH
RECYCLE WATER
SCREEN AND WASH
RECYCLE WATER
HEAVY MEDIA SEPARATION
RECYCLE WATER
WASH
GRIND
PRODUCT
WASH
MEDIA RECOVERY
POND
SUMP
RECYCLE TO PROCESS

GYPSUM MINING AND PROCESSING
(HMS)

No process water is used in the mining, crushing, or grinding of gypsum. However, mine or quarry pumpout is necessary in a number of facilities. Pumpout is not related to a production unit of gypsum, and the flow is independent of facility processing capacities. Most pumpouts are controlled with a pit or low-area sump which discharges when the water level reaches a certain height. Incidental water use includes non-contact cooling water for crusher bearings.

WET SCRUBBING

Since the completion of the contractor's study, all gypsum processing facilities have either changed to dry dust collection systems or employ total containment/recycle systems.

HEAVY MEDIA SEPARATION

Two facilities at the same general location beneficiate crude gypsum ore using heavy media separation (HMS) prior to processing. Both facilities follow the same process which includes quarrying, primary and secondary crushing, screening and washing, heavy media separation, washing, processing of float gypsum ore and stockpiling of sink dolomitic limestone. Magnetite and ferrous silica are used in both facilities as the separation media, with complete recirculation of the media or pulp.

Facility 1100 uses 1270 l/kkg (305 gal/ton) of ore processed in heavy media separation screening and washing which accounts for all process water. Additional water includes quarry pumpout. During periods of heavy rainfall, a discharge of up to 189,000 l/day (50,000 GPD) of quarry sump water may occur. As is typical with quarry pumpout, discharge is controlled by a sump, located at the low end of the quarry. Facility 1100 does not use non-contact cooling water for gypsum beneficiation.

ASPHALTIC MINERALS (SIC 1499)

This category of materials encompasses three basic types of materials produced by three different processes: bituminous limestone which is dry quarried; oil impregnated diatomite produced by dry methods; and gilsonite and other bituminous shales produced by wet processes. The processing of these minerals are depicted in Figure 21.

BITUMINOUS LIMESTONE

Bituminous limestone is dry surface mined, crushed, screened and shipped as product.

OIL IMPREGNATED DIATOMITE

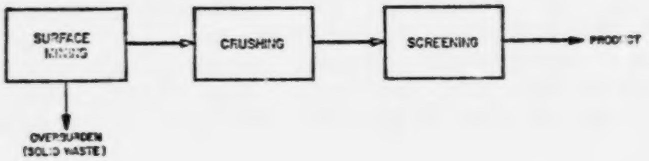
This material is produced at only one site (facility 5510). Oil impregnated diatomite is surface mined, crushed, screened and then calcined (burned) to free it of oil. The calcined material is then ground and prepared for sale. The only process water usage is a wet scrubber used to treat the vent gases from the calcination step. The scrubber waters are recycled.

GILSONITE

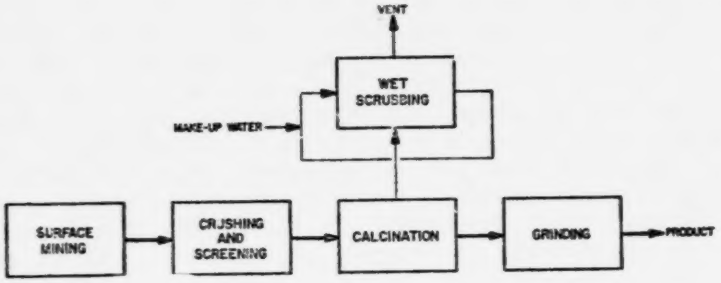
Gilsonite is mined underground. The ore is conveyed to the surface as a slurry and separated into a gilsonite slurry and sand, which is discarded as a solid waste. The gilsonite slurry is screen separated to recover product. Further processing by centrifuge and froth flotation recover additional material. These solids are then dried and shipped as product. Water use at facility 5511 is given below. A considerable amount of intake water is used for non-process purposes (i.e., drinking and irrigation). All process and mine pumpout waters are currently discharged.

	l/kkg of product (gal/ton)
intake	5,700 (1,400)
process	3,400 (820)
mine pumpout	470 - 1,800 (110-430)
drinking and irrigation	2,300 (550)

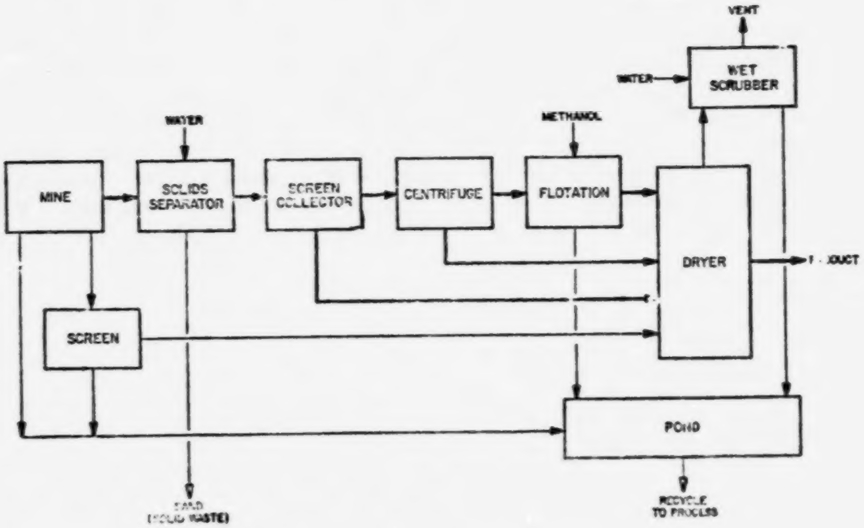
FIGURE 21


SURFACE MINING
CRUSHING
SCREENING
PRODUCT
OVERBURDEN (SOLID WASTE)

BITUMINOUS LIMESTONE MINING AND PROCESSING


VENT
WET SCRUBBING
MAKE-UP WATER
SURFACE MINING
CRUSHING AND SCREENING
CALCINATION
GRINDING
PRODUCT

OIL IMPREGNATED DIATOMITE MINING AND PROCESSING


VENT
WATER
WET SCRUBBER
WATER
METHANOL
MINE
SOLIDS SEPARATOR
SCREEN COLLECTOR
CENTRIFUGE
FLOTATION
DRYER
PRODUCT
SCREEN
POND
SAND (SOLID WASTE)
RECYCLE TO PROCESS

GILSONITE MINING AND PROCESSING

ASBESTOS AND WOLLASTONITE

ASBESTOS (SIC 1499)

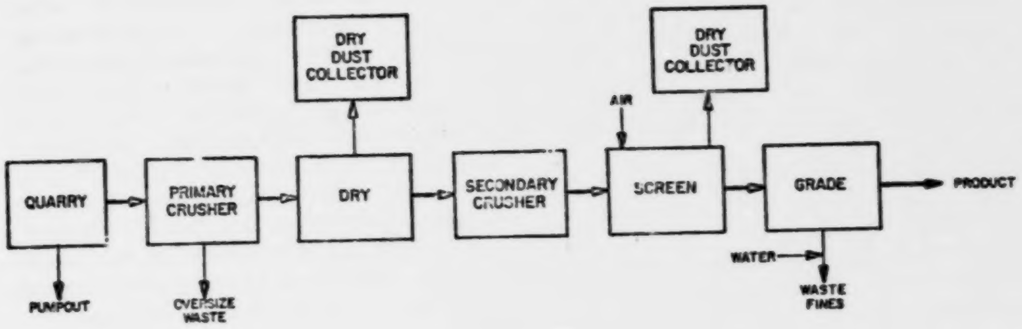
Processing of asbestos ore principally involves repeated crushing, fiberizing, screening, and air separation. Five facilities mine and process asbestos in the United States, four process by dry methods the fifth by wet methods. Figure 22 shows the different methods of processing.

ASBESTOS, DRY PROCESS

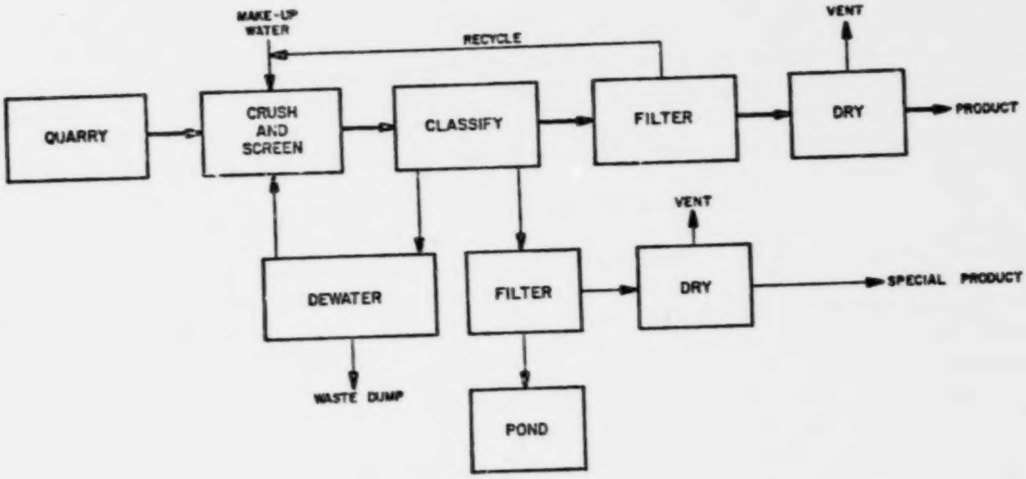
Asbestos ore is usually extracted from an open pit or quarry. At three facilities the fiber-bearing rock is removed from an open pit. At facility 1061 the ore is simply "plowed", allowed to air-dry, and the coarse fraction is screened out from the mill feed. After quarrying, the asbestos ore containing approximately 15% moisture is crushed, dried in a rotary dryer, crushed, and then sent to a series of shaker screens where the asbestos fibers are separated from the rock and air classified according to length into a series of grades. The collection of fibers from the shaker screens is accomplished with cyclones, which also aid in dust control. Asbestos processing involves fiber classification based on length, and as such, the raw waste loads consist of both oversize rock and undersize asbestos fibers which are unusable due to their length (referred to as "shorts"). At facility 1061 28 percent of the asbestos ore is rejected as oversize waste. At the processing facility another 65 percent of the feed are unusable asbestos fiber wastes which must be disposed of.

No process water is used for the dry processing of asbestos at any of the four facilities in this subcategory. Facility 3052 must continuously dewater the quarry of rain and ground water that accumulates. The flow is from 380 l/min to 2270 l/min (100 to 600 gal/min) depending on rainfall. The quantity of discharge is not related to production rate of asbestos. Facility 1061 uses water for dust suppression which is sprayed onto the dry asbestos tailings to facilitate conveying of tailings to a waste pile. The water absorbed in this manner amounts to 17 l/kkg of tailings (4 gal/ton).

FIGURE 22


DRY
DUST
COLLECTOR
DRY
DUST
COLLECTOR
AIR
QUARRY
PRIMARY
CRUSHER
DRY
SECONDARY
CRUSHER
SCREEN
GRADE
PRODUCT
WATER
PUMPOUT
OVERSIZE
WASTE
WASTE
FINES

ASBESTOS MINING AND PROCESSING
(DRY)


MAKE-UP
WATER
RECYCLE
VENT
QUARRY
CRUSH
AND
SCREEN
CLASSIFY
FILTER
DRY
PRODUCT
VENT
DEWATER
FILTER
DRY
SPECIAL PRODUCT
WASTE DUMP
POND

ASBESTOS MINING AND PROCESSING
(WET)

ASBESTOS, WET PROCESS

The only facility in this subcategory, facility 1060, mines the asbestos ore from a quarry located approximately 50 miles from the processing facility. The ore is "plowed" in horizontal benches, allowed to air-dry, screened and transported to the facility for processing. Processing consists of screening, wet crushing, fiber classification, filtering, and drying. Process water is used for wet processing and classifying of asbestos fibers. Facility 1060 uses 4,300 l/kkg (1,025 gal/ton) of asbestos milled. Approximately 4 percent of the water is incorporated into the end product which is a filter cake of asbestos fibers (50% moisture by weight). Eight percent is lost in the tailings disposal. Sixty eight percent is recirculated back into the process, and 20 percent is eventually discharged from the facility. The following tabulates estimated process water use at facility 1060:

	l/kkg of feed	gal/ton of feed
process water	4,300	1,025
water lost with product	150	36
water lost in tailings	350	84
water recirculated	2,900	700
water discharged to settling pond	860	205

This facility is unable to recirculate the water from the settling pond because of earlier chemical treatment given the water in the course of production of a special asbestos grade. The recirculation of this effluent would affect the quality of the special product. In addition to process water, facility 1060 uses 2,100 l/kkg of feed (500 gal/ton) of non-contact cooling water, none of which is recirculated.

WOLLASTONITE (SIC 1499)

There is only one producer of wollastonite in the U.S. (facility 3070). Wollastonite ore is mined by underground room and pillar methods, and is trucked to the processing facility. Processing is dry and consists of 3 stage crushing with drying following primary crushing. After screening, various sizes are fed to high-intensity magnetic separators to remove garnet and other ferro-magnetic impurities. The purified wollastonite is then ground in pebble or attrition mills to the desired product sizes. A general process diagram is given in Figure 23. Municipal water serves as the source for the sanitary and non-contact cooling water used in the facility. This amounts to 235 l/kkg of product (56 gal/ton).

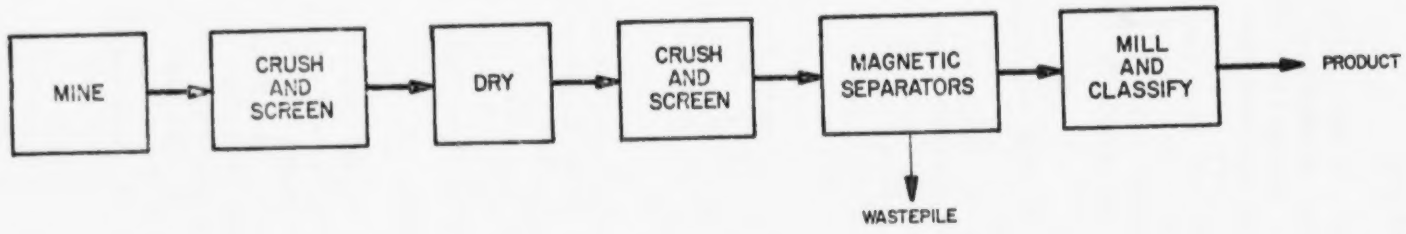

MINE
CRUSH AND SCREEN
DRY
CRUSH AND SCREEN
MAGNETIC SEPARATORS
WASTEPILE
MILL AND CLASSIFY
PRODUCT

FIGURE 23
WOLLASTONITE MINING AND PROCESSING

LIGHTWEIGHT AGGREGATE MINERALS (SIC 1499)

PERLITE

New Mexico produces 87 percent of the U.S. crude perlite. Three of four major perlite producers in New Mexico were inspected. All U.S. perlite facilities are in the same geographic region, and the processes are all dry. All the operations are open pit quarries using either front-end loaders or blasting to remove the ore from the quarry. The ore is then hauled by truck to the mills for processing. There the ore is crushed, dried, graded (sized), and stored for shipping. A general process diagram is given in Figure 24.

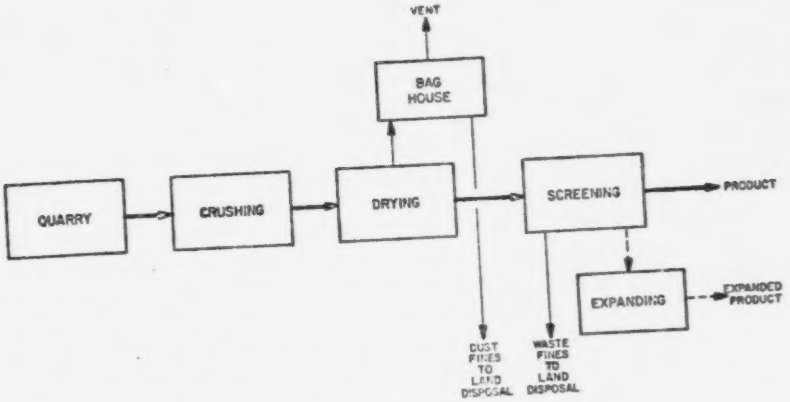
Perlite is expanded into lightweight aggregate for use as construction aggregate, insulation material, and filter medium. Expansion of perlite is done by injection of sized crude ore into a gas- or oil-fired furnace above 760°C (1,400°F). The desired temperature is the point at which the specific perlite being processed begins to soften to a plastic state and allows the entrapped water to be released as steam. This rapidly expands the perlite particles. Horizontal rotary and vertical furnaces are commonly used for expanding perlite. In either case, there is no process water involved. Horizontal rotary furnaces occasionally require non-contact cooling water for bearings. Facility 5500 does dewater the quarry when water accumulates, but this water is evaporated on land.

The oversize materials, processing and baghouse fines are hauled to the mine areas and land-disposed. There is work being done by facilities 5501 and 5503 to reclaim further product grades from the waste fines. Facility 5501 is investigating the use of water to make pellets designed to make land-disposal of fines easier and more efficient.

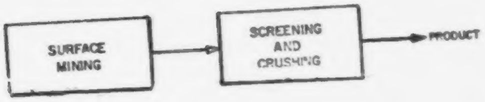
PUMICE

Pumice is surface mined in open pit operations. The material is then crushed, screened, and shipped for use as either aggregate, cleaning powder or abrasive. A process flowsheet is given in Figure 24. At most operations, no water is employed. This is true for facilities 1702, 1703, 1704, 5665, 5667 and 5669. At facility 1701 a small amount of water (10.55 l/kkg product) is used for dust control purposes, but this is absorbed by the product and not discharged. At facility 1705 a wet scrubber is used for dust control purposes.

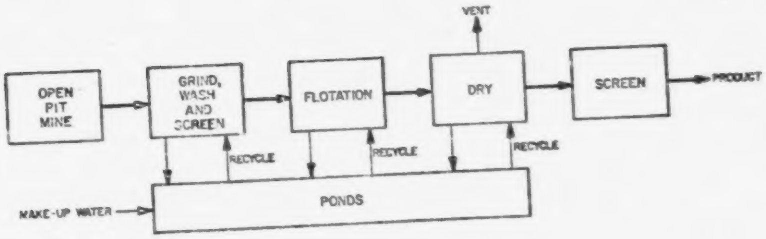
FIGURE 24


VENT
BAG HOUSE
QUARRY
CRUSHING
DRYING
SCREENING
PRODUCT
EXPANDING
EXPANDED PRODUCT
DUST FINES TO LAND DISPOSAL
WASTE FINES TO LAND DISPOSAL

PERLITE MINING AND PROCESSING


SURFACE MINING
SCREENING AND CRUSHING
PRODUCT

PUMICE MINING AND PROCESSING


VENT
OPEN PIT MINE
GRIND, WASH AND SCREEN
FLOTATION
DRY
SCREEN
PRODUCT
RECYCLE
RECYCLE
RECYCLE
MAKE-UP WATER
PONDS

VERMICULITE MINING AND PROCESSING

VERMICULITE

The mining of vermiculite at facility 5506 is conducted by bench quarrying using power shovels and loaders. Occasionally blasting is necessary to break up irregularly occurring dikes of syenite. Trucks then haul the ore to the process facility. The vermiculite is concentrated by a series of operations based on mechanical screening and flotation, a new process replacing one more dependent on mechanical separations. Sizer screens split the raw ore into coarse and fine fractions. The fines are washed, screened, and floated. After another screening the product is dewatered, dried and sent to the screening facility at another location. The coarse fraction is re-screened and the fines from this screening are hydraulically classified. Coarse fractions from screening and classification are sent to a wet rod-processing operation and recycled. The coarsest fraction from the hydraulic classification becomes tailings. The fines from hydraulic classification are screened, floated, re-screened and sent to join the other process stream at the dewatering stage.

The mining of vermiculite at facility 5507 is conducted by open pit mining using scrapers and bulldozers to strip off the overburden. The ore is then hauled to the facility on dump trailer-tractor haul units. The overburden and sidewall waste is returned to the mine pit when it is reclaimed. The vermiculite ore is fed into the process facility where it is ground and deslimed. The vermiculite is then sent to flotation. After flotation, the product is dried, screened, and sent to storage for eventual shipping. Figure 24 is a flow diagram showing the mining and processing of vermiculite.

Facility 5507 uses surface springs and runoff as source and make-up water. At facility 5506, water from 2 local creeks provides both source and make-up water for the vermiculite operations. In dry weather a nearby river becomes the make-up water source. A well on the property provides sanitary and boiler water. Since the only water loss is through evaporation during drying operations and some unknown amount is lost through seepage from the ponds to ground water, the net amount of make-up water reflects this loss. There is also some water loss in processing.

At facility 5506 waste is generated from the two thickening operations, from boiler water bleed, and from the washdown stream that is applied at the coarse tails-solids discharge point. (This is used to avoid pumping a wet slurry of highly abrasive pyroxenite coarse solids.) At facility 5507, there is one waste stream from the desliming, flotation and drying operations. This stream consists of mineral solids, principally silicates such as actinolite, feldspar, quartz, and minor amounts of tremolite, talc, and magnetite (1,600 kg/kkg product).

MICA AND SERICITE (SIC 1499)

Mica and sericite are mined in open pits using conventional surface mining techniques. Sixteen significant U.S. facilities producing flake, scrap or ground mica were identified in this study. Six of these facilities are dry grinding facilities processing either mica obtained from company-owned mines or purchased mica from an outside supplier. Three facilities are wet grinding facilities, and seven are wet mica beneficiation facilities utilizing froth flotation and/or spirals, hydroclassifiers and wet screening techniques to recover mica. Additionally there are four known sericite producers in the U.S. Three of these companies surface mine the crude ore for brick facilities and a fourth company has a dry grinding facility and sells the sericite after processing. Figure 25 shows the various methods of processing.

DRY GRINDING OF MICA AND SERICITE

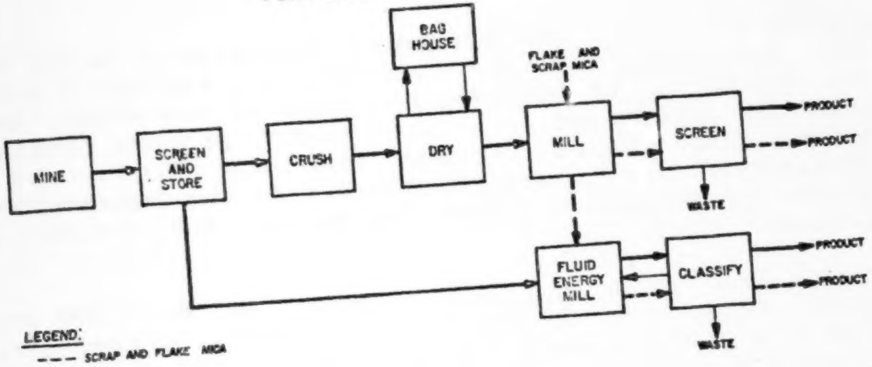
Dry grinding facilities are of two types, those which process ore obtained directly from the mine and others which process beneficiated scrap and flake mica. The ore from the mine is processed through coarse and fine screens before processing. The wastes generated from the two screening operations consist of rocks, boulders, etc., which are bulldozed into stockpiles. The crude ore is next fragmented, dried and sent to a hammer mill. In those facilities which process scrap and flake mica, the feed is sent directly into the hammer mill or into a pulverizer. In both types of facilities, the milled product is passed through a series of vibrating screens to separate various sizes of product for bagging. The waste material from the screening operations consists of quartz and schist pebbles.

In some facilities either the screened ore or the scrap and flake mica is processed in a fluid energy process facility. The ground product, in these facilities, is next classified in a closed circuit air classifier to yield various grades of products. Dry grinding facilities utilize baghouse collectors for air pollution control. The dust is reclaimed from these collectors and marketed.

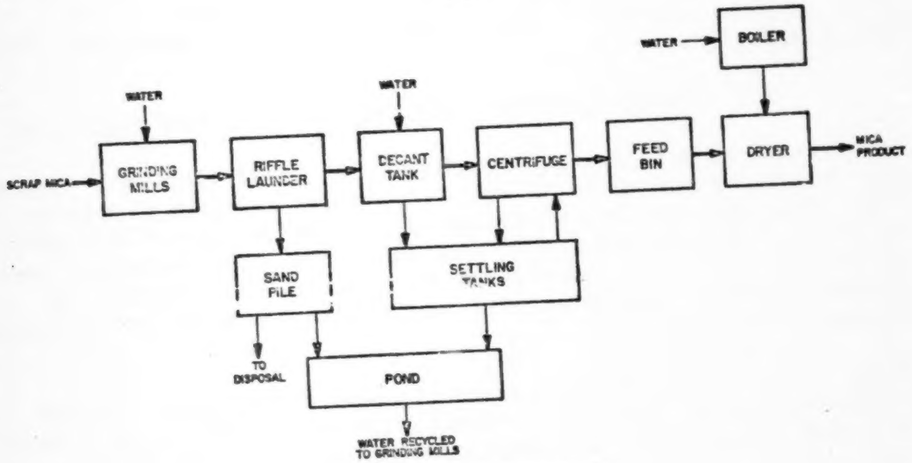
WET GRINDING OF MICA AND SERICITE

In a typical wet grinding facility, scrap and flake mica is batch milled in a water slurry. The mica rich concentrate from the process facility is decanted, dried, screened, and then bagged. The mica product from these facilities is primarily used by the paint, rubber, and plastic industries. The tailings from the process facility are dewatered to

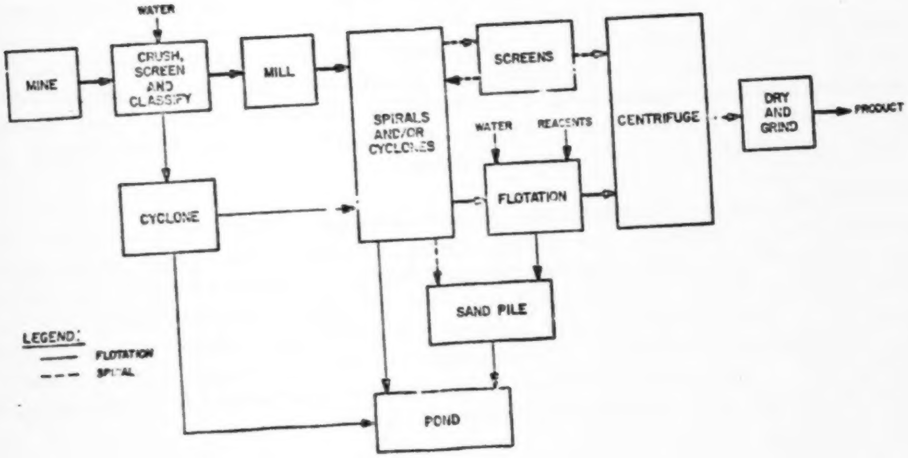
FIGURE 25


BAG HOUSE
FLAKE AND SCRAP MICA
MINE
SCREEN AND STORE
CRUSH
DRY
MILL
SCREEN
PRODUCT
PRODUCT
WASTE
FLUID ENERGY MILL
CLASSIFY
PRODUCT
PRODUCT
WASTE
LEGEND:
SCRAP AND FLAKE MICA

MICA MINING AND PROCESSING
(DRY)


WATER
BOILER
WATER
WATER
SCRAP MICA
GRINDING MILLS
RIFFLE LAUNDER
DECANT TANK
CENTRIFUGE
FEED BIN
DRYER
MICA PRODUCT
SAND PILE
SETTLING TANKS
TO DISPOSAL
POND
WATER RECYCLED TO GRINDING MILLS

MICA MINING AND PROCESSING
(WET)


WATER
MINE
CRUSH, SCREEN AND CLASSIFY
MILL
SPIRALS AND/OR CYCLONES
SCREENS
CENTRIFUGE
DRY AND GRIND
PRODUCT
WATER
REAGENTS
FLOTATION
CYCLONE
SAND PILE
POND
LEGEND:
FLOTATION
SPIRAL

MICA MINING AND PROCESSING
(FLOTATION OR SPIRAL SEPARATION)

remove the sand. The effluents emanating from the decanting and dewatering operations constitute the waste stream from the facility. At one facility visited the scrap and flake mica is processed in a fluid energy process facility using steam. The waste streams emanating from the boiler operations are sludge generated from the conventional water softening process, filter backwash, and boiler blowdown wastes.

Facilities 2059 and 2055 consume water at 4,900 and 12,500 l/kkg product (1,300 and 3,000 gal/ton), respectively. At facility 2055, about 80 percent of the water used in the process is make-up water, the remainder is recycled water from the decanting and dewatering operations. At facility 2059 makeup water is 1,500 l/kkg of product (360 gallons/ton); the remainder is recycled from the settling pond.

WET BENEFICIATION PROCESS OF MICA AND SERICITE

These ores contain approximately 5 to 15 percent mica. At the beneficiation facility, the soft weathered material from the stockpiles is hydraulically sluiced into the processing units. The recovery of mica from the ore requires two major steps, first, the coarse flakes are recovered by spirals and/or trommel screens and second, fine mica is recovered by froth flotation.

Five of the seven facilities discussed below use a combination of spiral classifiers and flotation techniques and the remaining two facilities use only spirals to recover the mica from the crude ore. Beneficiation includes crushing, screening, classification, and processing. The larger mica flakes are then separated from the waste sands in spiral classifiers. The fine sand and clays are deslimed, conditioned and sent to the flotation section for mica recovery. In facilities using only spirals, the underflow is screened to recover flaked mica. In both types of facilities, the mica concentrate or the flake mica is centrifuged, dried, and ground.

Although all flotation facilities use the same general processing steps, in some facilities, tailings are processed to recover additional by-products. Facility 2050 processes the classifier waste stream to produce clays for use by the brick industry and also processes the mica flotation tailings to recover feldspar. Facilities 2052 and 2057 process the classifier waste to recover a high grade clay for use by the ceramics industry.

The water used in these facilities is dependent upon the quantity and type of clay material in the crude ore. These facilities consume water at 69,500 to 656,000 l/kkg (16,700 to 157,000 gal/ton) of product. The hydraulic loads of these facilities are summarized as follows:

Facility	Process Water Used l/kkg of product	gal/ton
2050	95,200	22,800
2051	240,000	57,600
2052	125,000	30,000
2053	110,000	26,400
2054	69,500	16,700
2057	143,000	34,000
2058	656,000	157,000

Facility	Other Water Consumption l/kkg of product (gal/ton) process discharge	loss due evaporation, percolation and spills
2050	none	negligible
2051	none	negligible
2052	75,200 (18,000)	50,600 (12,100)
2053	none	80 (20)
2054	69,500 (16,700)	-------
2057	86,000 (20,600)	57,000 (13,700)
2058	none	-------

The raw waste load in these facilities consists of mill tailings, thickener overflow, and wastes from the various dewatering units. In some facilities, waste water from wet scrubbing operations is used for dust control purposes. The raw waste loads for these facilities are given as follows:

Facility	Clay, slimes, mica fines and sand wastes kg/kkg of product (lb/1000 lb)
2050	600
2051	14,400
2052	2,600
2053	4,000
2054	4,700
2057	2,900
2058	6,300

BARITE (SIC 1472)

There are twenty-seven significant U.S. facilities producing either barite ore or ground barite. Nine of these facilities are dry grinding operations, fourteen use log washing and jigging methods to prepare the ore for grinding and four are wet flotation facilities using froth flotation techniques for the beneficiation of the washed and/or jigged ore. Figure 26 depicts the different types of processing.

BARITE (DRY PROCESS)

The methods used in grinding barite depend upon the nature and condition of the ore to be ground and upon the application for which the mineral is to be sold. In a dry grinding mill, the ore from stockpiles is batched in ore bins. In most facilities the ore is soft and crushing is not necessary prior to the milling operation. In other cases, the ore is hard and must be crushed before grinding to free barite from the gangue material. After milling, the ground ore passes through a cyclone and a vibrating screen before being pumped into the product silos. From here it is either pumped to bulk hopper cars or to the bagging facility. The only waste is dust from baghouse collectors which is handled as a dry solid. No water is used in dry grinding facilities. There is no pumping of mine water in this subcategory.

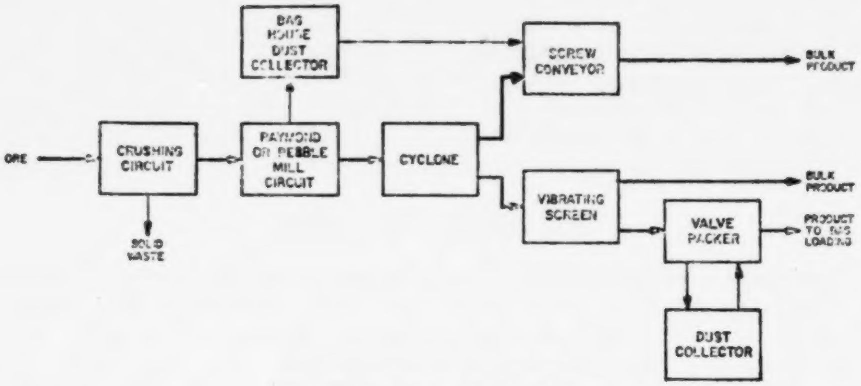
BARITE - WET PROCESS (LOG WASHING AND JIGGING OPERATIONS)

The wet processing facilities use washers or jigs to remove the clay from the barite ore. The mined ore is soft and is passed through a breaker and then fed to a log washer. The washed ore is next screened in a trommel circuit, dewatered and then jigged to separate gravel from the barite product.

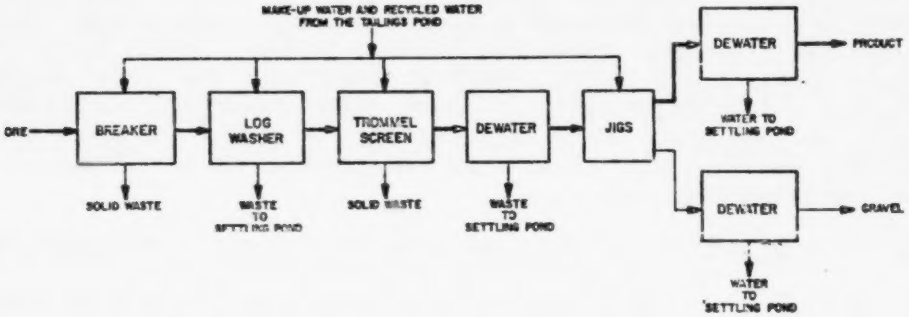
In facility 2013, the ore is first processed on a trommel screen to separate the fines (-3/4" material). The +1 1/2" material is then crushed and the resulting -4" barite product is sent to the stockpile. The +3/4 to 1 1/2" material is processed by jigging to separate gravel from the barite product.

In all these facilities, barite is mined in dry open pits. In most facilities, the clay strata is excavated by power shovel or dragline and hauled to the washing facility by dump trucks. In facility 2013, the barite and the waste (chert) is separated in the pit by a dozer, the ore is then dried in place, and the fines are separated by means of a trommel. Several caterpillar dozers with rippers are used

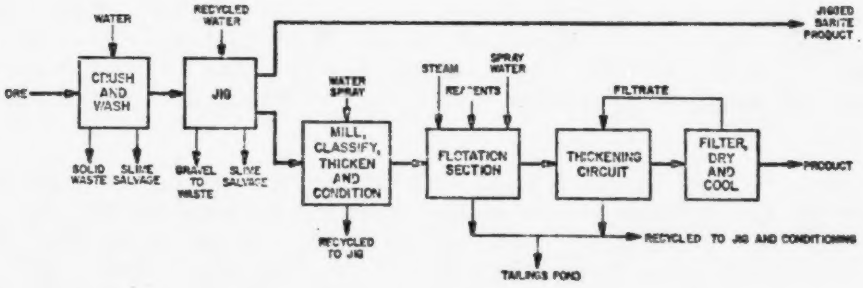
FIGURE 26


BAG HOUSE DUST COLLECTOR
SCREW CONVEYOR
BULK PRODUCT
ORE
CRUSHING CIRCUIT
RAYMOND OR PEBBLE MILL CIRCUIT
CYCLONE
VIBRATING SCREEN
BULK PRODUCT
VALVE PACKER
PRODUCT TO BAG LOADING
SOLID WASTE
DUST COLLECTOR

BARITE MINING AND PROCESSING
(DRY GRINDING PROCESS)


MAKE-UP WATER AND RECYCLED WATER FROM THE TAILINGS POND
ORE
BREAKER
LOG WASHER
TROMMEL SCREEN
DEWATER
JIGS
DEWATER
PRODUCT
WATER TO SETTLING POND
DEWATER
GRAVEL
SOLID WASTE
WASTE TO SETTLING POND
SOLID WASTE
WASTE TO SETTLING POND
WATER TO SETTLING POND

BARITE MINING AND PROCESSING
(WET PROCESS)


WATER
RECYCLED WATER
JIGGED BARITE PRODUCT
ORE
CRUSH AND WASH
JIG
WATER SPRAY
STEAM
REAGENTS
SPRAY WATER
FILTRATE
MILL, CLASSIFY, THICKEN AND CONDITION
FLOTATION SECTION
THICKENING CIRCUIT
FILTER, DRY AND COOL
PRODUCT
SOLID WASTE
SLIME SALVAGE
GRAVEL TO WASTE
SLIME SALVAGE
RECYCLED TO JIG
RECYCLED TO JIG AND CONDITIONING
TAILINGS POND

BARITE MINING AND PROCESSING
(FLOTATION PROCESS)

to excavate and push the ore into piles to be loaded and hauled to the crusher at the processing facility.

The quantity of the clay, sand and gravel, and rock in the ores mined in these facilities varies from location to location. The pure barite amounts to 3-7 percent by weight of the material mined. Some waste material is removed at the mine site without use of water.

The quantity of the water used in these facilities depends upon the quality of the ore and the type of the waste material associated with the ore as given as follows:

		water consumption in l/kkg of product (gal/ton)	
Facility	barite recovery from feed (%)	process water	sanitary and misc. usage
2011	63	62,600 (15,000)	650 (150)
2012	63	140,200 (33,600)	---
2013	77	7,200 (1,725)	---
2015	5.7	162,700 (39,000)	---
2016	4.8	239,400 (57,400)	---
2017	3.3	291,300 (69,800)	12,380 (3,270)
2018	3.9	246,500 (59,100)	8,382 (2,215)
2020	54	62,600 (15,000)	650 (150)
2046	63	140,200 (33,600)	---

The exceptional facility in the above table is 2013. This facility uses water at an average of only 7,200 l/kkg product (1,725 gal/ton) because only 30-40 percent of the ore goes through jigging. The majority of the barite at this facility is dry ground. In facilities 2012, 2013 and 2046, the process water volumes given include the water used for sanitary purposes. In all facilities, the process water is recycled. Makeup water may be required in some of these facilities.

The process raw wastes in this subcategory consist of the mill tailings from the washing and jigging circuits. These clay and sand wastes range from 230 to 970 kg per kkg of feed.

BARITE (FLOTATION PROCESS)

Processing in these facilities consists of crushing the ore to free it from the gangue material, washing the barite ore to remove the clay, jigging the washed ore to separate the gravel, grinding, and beneficiation by froth flotation to recover barite concentrates. The concentrates are then filtered and dried. Drying is at temperatures high enough to destroy the organic reagent used in the flotation. The dried product is then cooled and bagged for shipment. At facility 2019, two separate flotation circuits are used to recover barite fines from the log washer and jig tailings. In facility 2014, the ore from the mine is free from clays and sands, and this facility processes its ore without a washing and jigging operation.

The major process raw waste emanating from these facilities is the flotation mill tailings. The solids in the raw waste stream was reported to be an average of 24,750 mg/l and maximum of 50,000 mg/l for facility 2019. The quantities of the wastes are given as follows:

Facility	l/day (gal/day) 2010	 2014	 2019
Mill tailings	530,000 (140,000)	660,000 (173,500)	4,730,000 (1,250,000)
Washdown water from mill	265,000 (70,000)	110,000 (29,000)	--- unknown
Spent brine from water softening operation	---	19,000 (5,000)	---

Facility 2010 consumes water at an average of 45,000 l/kkg product (10,800 gal/ton) on a total recycle basis. This includes about 1,655 l/kkg product used for non-contact cooling, boiler feed and sanitary purposes. Most of the process water used in this facility, 13,025,000 l/day (3.44 mgd), is recycled back to the facility from the thickening operations. At facility 2014, well water is used both in the flotation circuit and for the milling operation. This facility consumes 2,500 l/kkg of product (595 gal/ton). Approximately 35 percent of this water is recycled from the thickening operations. The flotation tailings and some overflow from the thickener are sent to the tailings pond. At facility 2019 untreated river water is used as process water. This facility consumes an average of 33,700 l/kkg of product (8,900 gal/ton) on a once through basis. The hydraulic load of these facilities are given as follows:

Facility	l/day (gal/day) 2010	2014	2019
Makeup water	2,725,000 max. (720,000 max.)	792,000 (208,980)	4,731,000 (1,250,000)
Recycled water	13,025,000 (3,440,000)	427,000 (112,520)	---
Process consumed	15,750,000 (4,160,000)	872,000 (230,000)	4,731,000 (1,250,000)
Non-contact cooling	530,000 (140,000)	---	---
Sanitary	37,900 (10,000)	218,000 (57,500)	---
Boiler feed	37,900 (10,000)	---	---
Brine & back flush &rinse water used in water softening	---	19,000 (5,000)	---
Misc. housekeeping	---	110,000 (29,000)	---

FLUORSPAR (SIC 1473)

There are fifteen significant facilities in the U.S. producing either fluorspar concentrates and/or finished acid grade and metallurgical grade fluorspar products. Six of these facilities are wet heavy media separation (HMS) facilities, producing both a finished product (metallurgical gravel) and upgraded and preconcentrated feed for flotation. Five facilities use froth flotation for the production of fluorspar alone or with barite, zinc, or lead; three are fluorspar drying facilities drying imported filter cakes in kilns or air driers, and one is a fluorspar pelletizing facility, where spar filter cake is pressed to pellets, dried and shipped. Figure 27 shows the different methods of processing.

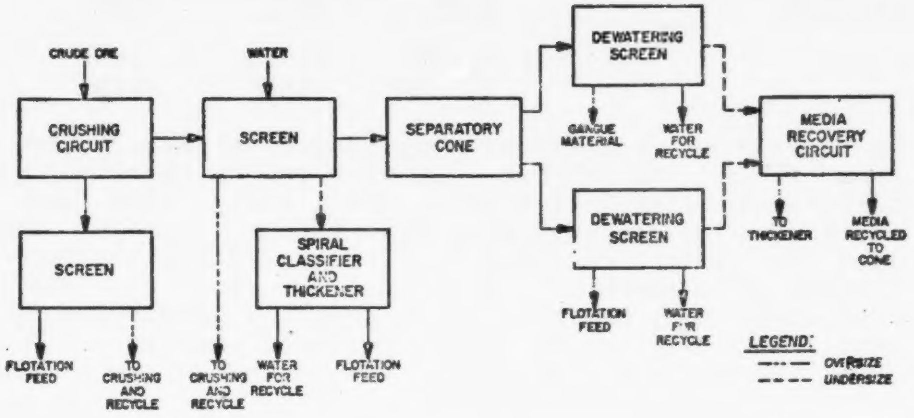
FLUORSPAR - HEAVY MEDIA SEPARATION (HMS) OPERATIONS

An HMS facility may serve two purposes. First, it upgrades and preconcentrates the ore to yield an enriched flotation feed. Second, it produces a metallurgical grade gravel. The ore is crushed to proper size in the crushing circuit, then washed and drained on vibrating screens to eliminate as many fines as possible. The oversize material from this operation is recycled back to the screen. The undersize is sent into a spiral classifier for recovery of a portion of the flotation facility feed. The HMS cone feed consists of the middle size particles resulting from the screening operation. The separatory cone contains a suspension of finely ground ferro-silicon and/or magnetite in water, maintained at a predetermined specific gravity. The light fraction (HMS tailings) floats and is continuously removed by overflowing a weir. The heavy particles (flotation feed) sink and are continuously removed by an airlift.

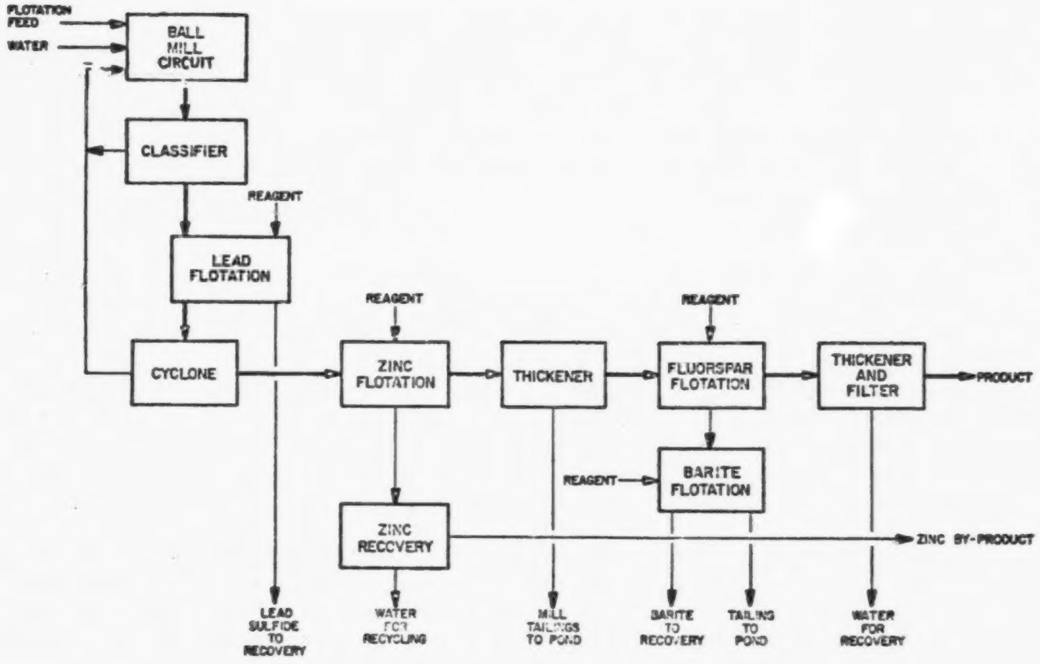
The float overflow and sink airlift discharge go to drainage screens where 95 percent of the medium carried with the float and sink drains through the screen, is magnetically separated from the slimes, and is returned to the circuit. The float and sink products are passed over dewatering screens and the water is pumped back to the facility.

Water consumption in these facilities ranges from 96 to 2700 l/kkg of feed to the facility (650-2300 gal/ton of feed). The hydraulic loads for the HMS facility were not known in two of the facilities (2008 and 2009) because the HMS and flotation facilities are located at the same site. They are operated as a combined unit and water consumption values were available for the combined operation. The hydraulic loads for the remaining facilities are given as follows:

FIGURE 27


CRUDE ORE
WATER
CRUSHING CIRCUIT
SCREEN
SEPARATORY CONE
DEWATERING SCREEN
GANGUE MATERIAL
WATER FOR RECYCLE
MEDIA RECOVERY CIRCUIT
SCREEN
SPIRAL CLASSIFIER AND THICKENER
DEWATERING SCREEN
TO THICKENER
MEDIA RECYCLED TO CONE
FLOTATION FEED
WATER FOR RECYCLE
FLOTATION FEED
TO CRUSHING AND RECYCLE
TO CRUSHING AND RECYCLE
WATER FOR RECYCLE
FLOTATION FEED
LEGEND:
OVERSIZE
UNDERSIZE

FLUORSPAR MINING AND PROCESSING
(HMS PROCESS)


FLOTATION FEED
WATER
BALL MILL CIRCUIT
CLASSIFIER
REAGENT
LEAD FLOTATION
REAGENT
REAGENT
CYCLONE
ZINC FLOTATION
THICKENER
FLUORSPAR FLOTATION
THICKENER AND FILTER
PRODUCT
REAGENT
BARITE FLOTATION
ZINC RECOVERY
ZINC BY-PRODUCT
LEAD SULFIDE TO RECOVERY
WATER FOR RECYCLING
MILL TAILINGS TO POND
BARITE TO RECOVERY
TAILING TO POND
WATER FOR RECOVERY

FLUORSPAR MINING AND PROCESSING
(FLOTATION PROCESS)

Water Consumption Facility	1/kkg of feed (gal/ton) 2004	2005	2006	2007
	9,600 (2,300)	2,710 (650)	3,670 (880)	5,550 (1,330)

Raw wastes in this subcategory consist primarily of slimes from fines separation. At five of the facilities in this subcategory (facilities 2004, 2005, 2006, 2008 and 2009), there is no waste discharge from the HMS process. The water used in these facilities is recycled back through closed circuit impoundments. At facility 2007 the raw waste, consisting of the classifier overflow is discharged into a settling pond prior to discharge. The average value of the raw slime waste for facility 2007 is 340 kg/kkg of product.

FLUORSPAR-FLOTATION OPERATIONS

There are currently five fluorspar flotation mills in operation in the U.S. Three of these operations are discussed below. A fourth facility is in the startup stage and operating at 30-40 percent of design capacity.

In froth flotation facilities, fluorspar and other valuable minerals are recovered leaving the gangue minerals as mill tailings. Facility 2000 recovers fluorspar, zinc and lead sulfides. Facility 2003 recovers fluorspar only. At facilities 2000 and 2001, lead and zinc sulfides are floated ahead of fluorspar using appropriate reagents as aerofloats, depressants and frothers. At facility 2000, barite is floated from the fluorspar rougher flotation tailings.

In all these facilities, steam is added to enhance the selectivity of the operation. The various grades of concentrates produced are then stored in thickeners until filtered. Barite, lead sulfide, and zinc sulfide concentrates are sold in filter cake form. The fluorspar concentrates are dried in rotary kilns. The dried concentrates are then shipped. At facility 2001, a portion of the fluorspar filter cake is sent to the pellet facility where it is mixed, pressed into pellets, dried and stored.

The ores have different physical characteristics and require different quantities of process water. A maximum of 20 percent of the process water is recycled from the thickeners. The remainder is discharged into a ponding system. The hydraulic loads for these facilities are:

	l/day (mgd)		
	2000	2001	2003
Process	1,700,000 (0.45)	3,425,000 (0.905)	1,090,000 (0.288)
Boiler feed	30,000 (0.008)	---	54,500 (0.014)
Non-contact cooling	38,000 (0.010)	54,000 (0.014)	---
Dust control	120,000 (0.032)	---	---
Sanitary uses	4,000 (0.001)	2,500 (0.0008)	---
Process waste	1,515,000 (0.40)	3,260,000 (0.865)	0
Water recycled or evaporated	377,000 (0.103)	196,500 (0.055)	1,144,500 (0.302)

	l/kkg of product (gal/ton)		
facility water use	11,900 (2,860)	20,200 (4,840)	21,030 (5,040)
process waste	9,540 (2,290)	19,100 (4,580)	0

The process raw wastes in this subcategory consist of the tailings from the flotation sections. At facilities 2000 and 2001, the tailings contain 14 to 18 percent solids, which consist of 4-5 percent CaF_2, 20-25 percent $CaCO_3$, 25-30 percent SiO_2, and the remainder is primarily shale and clay. The average values of the raw wastes are:

	kg/kkg of product (lb/1000 lb)		
	2000	2001	2003
flotation tailings	1,800	2,000	2,000

FLUORSPAR (DRYING AND PELLETIZING OPERATIONS)

There are presently three fluorspar drying facilities in the U.S. In these facilities imported filter cakes are dried and sold. The filter cake has about 9-10 percent moisture which is dried in kilns or in air driers. Two of these facilities have no discharge. They use baghouse collectors for dust control. The third drying facility is located at the same site as the company's hydrofluoric acid facility. This drying facility has an effluent from the wet scrubber on the drier, which is treated in the gypsum pond along with the acid facility effluent. The combined effluent stream has been covered under the Inorganic Chemical Manufacturing category.

There are two pelletizing facilities in the U.S. One of these operations has been discussed previously under flotation (facility 2001). A second facility manufactures fluorspar pellets only. At this facility fluorspar filter cake is mixed with some additives, pressed into pellets, dried and stored. No pollutants are generated at this facility site.

MINE DISCHARGE IN FLUORSPAR OPERATIONS

There are presently seven fluorspar active mines in the U.S. Six of these mines are underground operations (2088, 2089, 2090, 2091, 2092 and 2093) and one is a dry open-pit mine (2094). Additionally, there are three underground mines in the development stage (2085, 2086, 2087) with no current production and five other mines with no production but are dewatered (2080, 2081, 2082, 2083 and 2084).

Mine 2080 is used as an emergency escape shaft, air shaft, and also to help dewater mine 2088. There are no discharge waters pumped from either mines 2084 and 2087. What water there is in these mines drains underground and eventually enters mine 2083. It has been estimated that mine 2085 will have a discharge volume in the vicinity of 3,800,000 l/day (1 mgd). The present discharge is only a small fraction of the anticipated volume of water from this mine. At mines 2091 and 2093, about 62 and 40 percent, respectively, of the mine discharge water is used at the mills. The remaining drainage is then discharged.

SALINES FROM BRINE LAKES (SIC 1474)

The extraction of several mineral products from lake brines is carried out at three major U.S. locations: Searles Lake, California; Silver Peak, Nevada; and the Great Salt Lake, Utah. The operations at these locations are integrated and the water and waste handling cannot be readily attributed to the separate products. The facilities at Searles Lake operate what is called the "Trona Process", not to be confused with the trona ore mining in Sweetwater County, Wyoming, discussed elsewhere. This complex process produces many products based on the brine constituents. The process operated at the Great Salt Lake produces a smaller number of products. However, the waste handling and disposal techniques at all locations are quite similar.

SEARLES LAKE OPERATIONS

Several minerals such as borax, lithium salts, salt cake, natural soda ash and potash are produced from the brine of Searles Lake, California, by a series of processing steps involving evaporation of the brine in stages with selective precipitation of specific ingredients. The recovery processes and raw material are unique to this location. These processes are carried out in a desert area adjacent to Searles Lake, a large residual evaporate salt body filled with saline brines. About 14 percent of the U.S. potash production is from this source, 74 percent of the U.S. natural sodium sulfate, 17 percent of the U. S. borax, and 12 percent of the natural soda ash.

At facility 5872, the brines are the raw material and are pumped into the processing facilities where the valuable constituents are separated and recovered. The residual brines, salts and end liquors including various added process waters are returned to the lake to maintain the saline brine volume and to permit continued extraction of the valuable constituents in the return water. There is no discharge as the recycle liquors are actually the medium for obtaining the raw material for the processes. Total brine flow into the facility is about 33,600,000 l/day (9.0 mgd) with about one quarter being lost by evaporation. The total recycle back to the salt body is the same volume, including added process waters.

For potash production at Searles Lake, a cyclic evaporation-crystallization process is used in which about 16,350,000 l/day (4.32 mgd) of saline brine are evaporated to dryness. The brine, plus recycle mother liquor, is concentrated in triple effect steam evaporators to produce a hot concentrated liquor high in potassium chloride and borax. As the concentration proceeds, large amounts of salt (NaCl) and burkeite (Na_2CO_3, Na_2SO_4) are crystallized and separated. The former is returned to the salt body and the latter, which also contains dilithium sodium phosphate is transported to another process for separation into soda ash (Na_2CO_3), salt cake (Na_2SO_4), phosphoric acid and lithium carbonate. The hot concentrated liquor is cooled rapidly in vacuum crystallizers and potassium chloride is filtered from the resulting slurry. Most of the potassium chloride is dried and packaged while a portion is refined and/or converted into potassium sulfate. The cool liquor, depleted in potassium chloride, is held in a second set of crystallizers to allow the more slowly crystallizing borax to separate and be filtered away from the final mother liquor which is recycled to the evaporation-concentration step to complete the process cycle. The borax, combined with borax solids from the separate carbonation-refrigeration process, is purified by recrystallization, dried, and packaged. A process flow sheet is given in Figure 28.

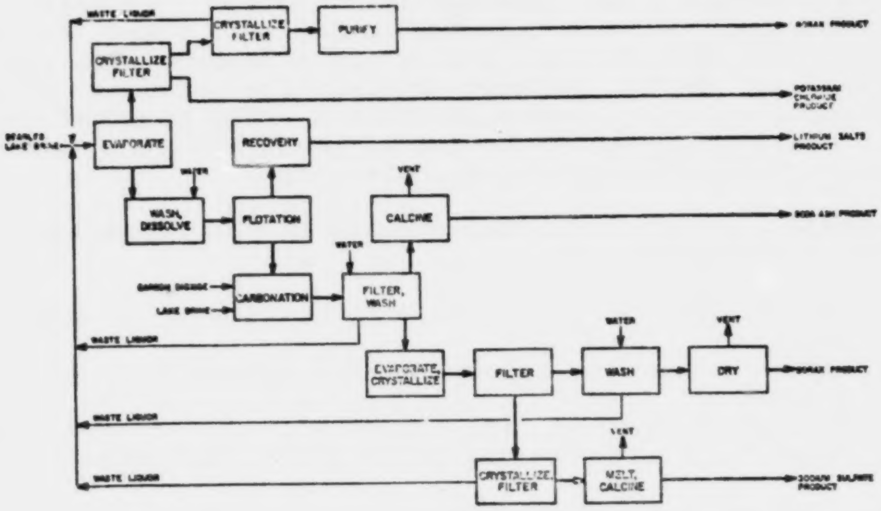
The wastes from the basic evaporation-crystallization process, including the processes for potassium chloride, borax, soda ash, and salt cake, are weak brines made up of process waters, waste salts and end liquors. These are returned to the salt body in an amount essentially equal to the feed rate to the process--about 16,350,000 l/day (4.32 mgd). The recycle liquors enter both the upper and lower structures of the salt body. In the case of the carbonation-refrigeration system, the entire brine stream, depleted in sodium carbonate and borax, is recycled to the salt body to continue the solution mining. The overall water usage for the two facilities is about 33,600,000 l/day (8.88 mgd) of Searles Lake brine with about one-third of this volume of fresh water used for washing operations.

GREAT SALT LAKE RECOVERY OPERATIONS

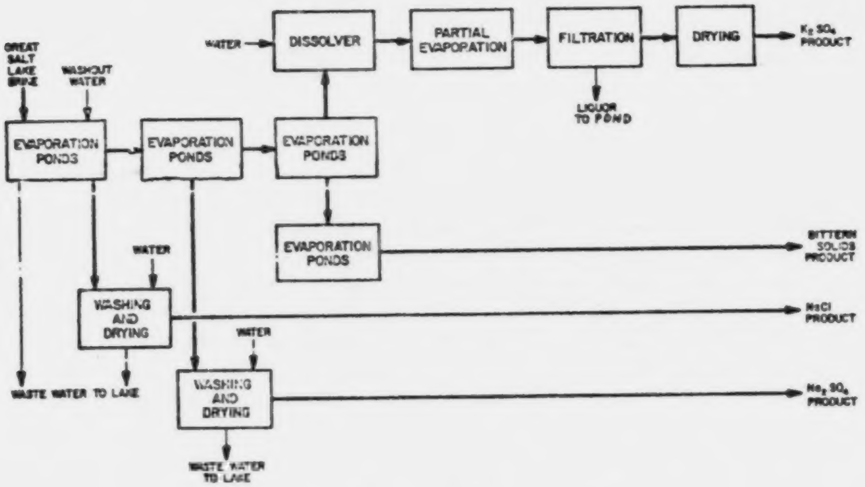
At the present time four mineral products are produced at this location: sodium chloride, sodium sulfate, potassium sulfate and bittern liquors. Recovery of pure lithium and magnesium salts is being planned for the future. About 20 percent of the U.S. natural sodium sulfate comes from this location.

Brine from the north arm of Great Salt Lake is pumped into a series of evaporation ponds. Partial evaporation occurs selectively precipitating out sodium chloride. The residual brine is pumped to a second series of ponds for further evaporation and the precipitated salts are harvested.

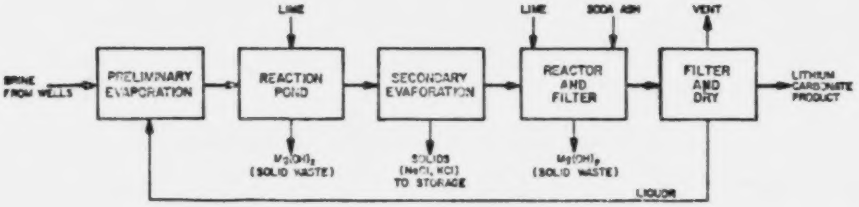
FIGURE 28


WASTE LIQUOR
CRYSTALLIZE FILTER
PURIFY
BORAX PRODUCT
CRYSTALLIZE FILTER
POTASSIUM CHLORIDE PRODUCT
SEARLES LAKE BRINE
EVAPORATE
RECOVERY
LITHIUM SALTS PRODUCT
WATER
VENT
WASH, DISSOLVE
FLOTATION
CALCINE
SODA ASH PRODUCT
WATER
CARBON DIOXIDE
LAKE BRINE
CARBONATION
FILTER, WASH
WASTE LIQUOR
WATER
VENT
EVAPORATE, CRYSTALLIZE
FILTER
WASH
DRY
BORAX PRODUCT
WASTE LIQUOR
VENT
WASTE LIQUOR
CRYSTALLIZE, FILTER
MELT, CALCINE
SODIUM SULFATE PRODUCT

MINERALS RECOVERY FROM SEARLES LAKE


WATER
DISSOLVER
PARTIAL EVAPORATION
FILTRATION
DRYING
K_2SO_4 PRODUCT
GREAT SALT LAKE BRINE
WASHOUT WATER
LIQUOR TO POND
EVAPORATION PONDS
EVAPORATION PONDS
EVAPORATION PONDS
EVAPORATION PONDS
BITTERN SOLIDS PRODUCT
WATER
WASHING AND DRYING
NaCl PRODUCT
WATER
WASTE WATER TO LAKE
WASHING AND DRYING
Na_2SO_4 PRODUCT
WASTE WATER TO LAKE

MINERALS RECOVERY AT GREAT SALT LAKE


LIME
LIME
SODA ASH
VENT
BRINE FROM WELLS
PRELIMINARY EVAPORATION
REACTION POND
SECONDARY EVAPORATION
REACTOR AND FILTER
FILTER AND DRY
LITHIUM CARBONATE PRODUCT
$Mg(OH)_2$ (SOLID WASTE)
SOLIDS (NaCl, KCl) TO STORAGE
$Mg(OH)_2$ (SOLID WASTE)
LIQUOR

LITHIUM SALT RECOVERY
NATURAL BRINE, SILVER PEAK OPERATIONS

In the second series of ponds, further evaporation of the brine occurs to precipitate sodium sulfate. The concentrated residual brine is pumped to a third series of ponds and the sodium sulfate is harvested. In the third series of ponds, further evaporation occurs effecting precipitation of potassium sulfate. The residual brine is then pumped to a fourth series of ponds for bittern recovery and the potassium sulfate is harvested.

The harvested raw salts are treated in the following manners prior to shipment:

(a) Sodium chloride is washed with fresh water, dried, and packaged.
(b) Sodium sulfate is treated in the same manner as sodium chloride.
(c) Potassium sulfate is dissolved in fresh water, recrystallized from solution, dried, and packaged.

The washwaters from the sodium sulfate and chloride purifications and waste water from the recrystallization of potassium sulfate are discharged to the Great Salt Lake. A process flowsheet is given in Figure 28. There is also some discharge due to yearly washout of the evaporation ponds with fresh water. These are all returned to the Great Salt Lake.

Eleven million liters per day (2.9 mgd) of waste water arises from two sources: washing of the recovered sodium chlorides and sulfate, and recrystallization of recovered potassium sulfate. The waste water from these operations contains these three substances as constituents along with minor amounts of materials present in lake brine bitterns (i.e., magnesium salts). Since the waste water constituents are similar to the lake brine, these wastes are discharged without treatment back to the Great Salt Lake. The compositions of the intake brine and effluent wash water are, in terms of mg/l:

	lake brine	facility discharge
sodium	96,800	33,450
magnesium	49,600	99,840
chloride	160,000	78,000
sulfate	14,500	55,500
TSS	1945	703

SILVER PEAK, NEVADA, OPERATIONS

This facility manufactures lithium carbonate. Brine containing lithium salts is pumped to the surface to form a man-made brine lake. This consists of a series of evaporation ponds for preliminary concentration. After this step, the brine is then treated with lime to precipitate magnesium salts as the hydroxide. The magnesium hydroxide is recovered periodically from the ponds as a precipitant.

The treated brine is then further concentrated by evaporation to partially precipitate sodium and potassium salts. These are periodically harvested from the ponds and stored for future processing to recover potash values. The concentrated brine is again reacted with soda ash, and the precipitated lithium carbonate is filtered, dried, and packaged. The spent brine is returned to the preliminary evaporation ponds for mixing with fresh material. A process flowsheet is given in Figure 28.

Facility water consists of brine from an underground source and fresh water used for washout purposes. All of this water is evaporated during the process and all of the wastes produced as solids.

	l/kkg of product (gal/ton)
Process brine	1,500,000 (360,000)
Process washout water	36,800 (8,500)

BORAX (SIC 1474)

The whole U.S. production of borax is carried out in the desert areas of California by two processes: the mining of borax ore and the Trona process. This latter process is discussed in detail in the section on salines from brine lakes. The mining of ore accounts for about three-fourths of the estimated U.S. production of borax. The facility discussed herein is the only U.S. producer by this method.

Borax is prepared by extraction from a dry mined ore which is an impure form of sodium tetraborate decahydrate (borax). The ore is crushed, dissolved in water (mother liquor), and the solution is fed to a thickener where the insolubles are removed and the waste is sent to percolation- proof evaporation ponds. The borax solution is piped to crystallizers and then to a centrifuge, where solid borax is recovered. The borax is dried, screened and packaged and the mother liquor recycled to the dissolvers. A process flow diagram is given in Figure 29.

Fresh water consumption at the facility amounts to 2,840 l/kkg (680 gal/ton). An additional 835 l/kkg (200 gal/ton) enters via the ore. Most of the cooling water is recycled and all the process waste water is sent to evaporation ponds.

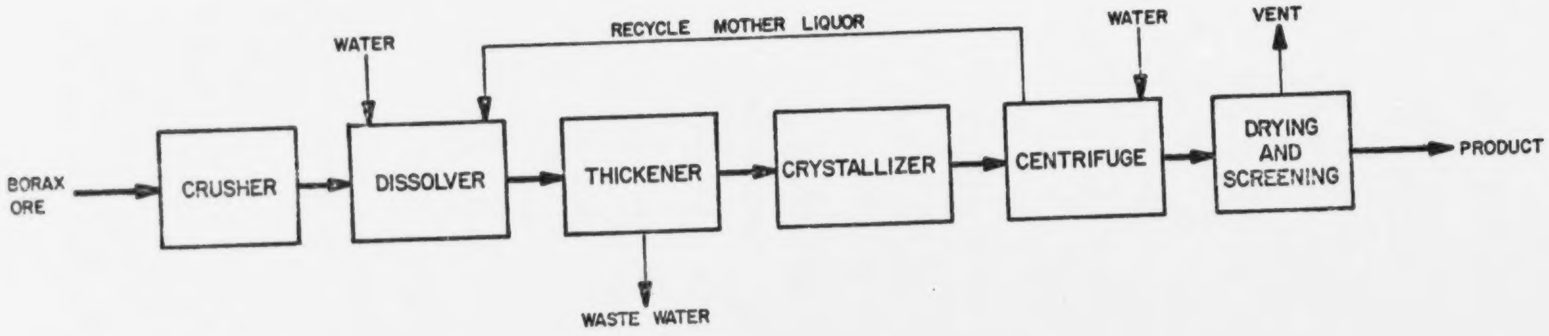

BORAX ORE
CRUSHER
WATER
DISSOLVER
RECYCLE MOTHER LIQUOR
THICKENER
WASTE WATER
CRYSTALLIZER
WATER
CENTRIFUGE
VENT
DRYING AND SCREENING
PRODUCT

FIGURE 29
BORATE MINING AND PROCESSING

POTASH (SIC 1474)

Potash is produced in four different geographical areas by four different processing methods. These methods are:

(1) Dry mining of sylvinite ores is followed by flotation or selective crystallization to recover potash as potassium chloride from the sylvinite and dry mining of langbeinite ores is followed by leaching to recover potash as langveinite from the ores. A portion of the leached langbeinite, usually fines from product screening, is reacted in solution with potassium chloride to produce potassium sulfate and magnesium chloride. The latter is either recovered as a co-product or discarded as a waste. These are the processes employed in the Carlsbad, New Mexico, area operations.

(2) Solution mining of Searles Lake brines is followed by several partial evaporation and selective crystallization steps to recover potash as KCl. During the several process steps, 12 other mineral products are also recovered. This is discussed earlier.

(3) Solution mining is performed from Utah sylvinite deposits. This method is used to recover potash as a brine, which is then evaporated. The solids are separated by flotation to recover potassium chloride. The sodium chloride is a solid waste.

(4) Evaporation of Great Salt Lake brines is similar to the Searles Lake operation in that the brine is evaporated in steps to selectively recover sodium chloride and sulfate and potassium sulfate. The latter product is purified by recrystallization. All of the wastes from this process which consist of unrecovered salts are returned to the lake. This is also discussed earlier.

CARLSBAD OEPRATIONS

There are two processes employed in the six Carlsbad area facilities which account for about 84 percent of the U.S. production of potash. One is used for recovery of potassium chloride and the other for processing langbeinite ores. Sylvinite ore is a combination of potassium and sodium chlorides. The ore is mined, crushed, screened and wet ground in brine. The ore is separated from clay impurities in a desliming process. The clay impurities are fed to a gravity separator which removes some of the sodium chloride precipitated from the leach brine and the insolubles for disposal as waste. After desliming, the ore is prepared for a flotation process, where potassium and sodium chlorides are separated. The tailings slurry and the potassium chloride slurry are centrifuged, and the brines are returned to the process circuit. These tailings are then wasted, and the sylvite product is dried, sized and shipped or stored. A process flowsheet is given in Figure 30. Langbeinite is a natural sulfate of potassium and magnesium, $K_2Mg_2(SO_4)_3$, and is intermixed with sodium chloride. This ore is mined, crushed, and the sodium chloride is removed by leaching with water. The resulting langbeinite slurry is centrifuged with the brine being wasted and the langbeinite dried, sized, shipped or stored.

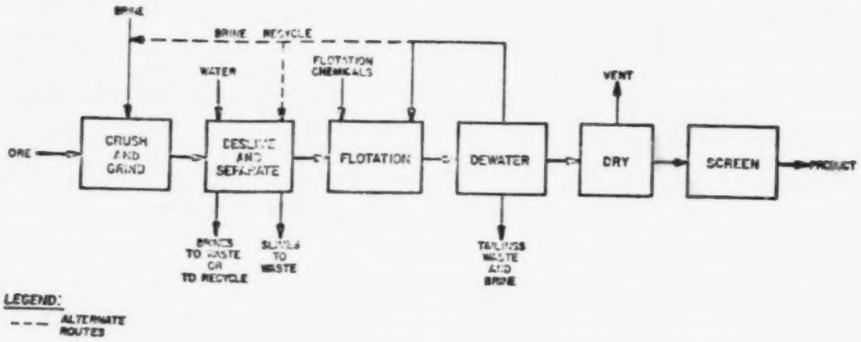
A portion of the langbeinite, usually the fines from sizing, are reacted in solution with potassium chloride to form potassium sulfate. Partial evaporation of a portion of the liquors is used to increase recovery. The remaining liquor from the evaporation step is either wasted to an evaporation pond or evaporated to dryness to recover magnesium chloride as a co-product. The disposition of the waste liquor is determined by the saleability of the magnesium chloride co-product and the cost of water to the facility. The potassium sulfate slurry from the reaction section is centrifuged with the liquor returned to the facility circuit, and the resulting potassium sulfate product is dried, sized, shipped or stored. A simplified process flowsheet is given in Figure 30.

All six facilities at Carlsbad processing sylvinite ore are described above. Two process langbeinite only. One facility processes langbeinite ore in addition to sylvinite. In that case, the ore is dry mined, crushed and cold leached to remove sodium and potassium chlorides. The material is then washed free of clays, recovered, dried and packaged.

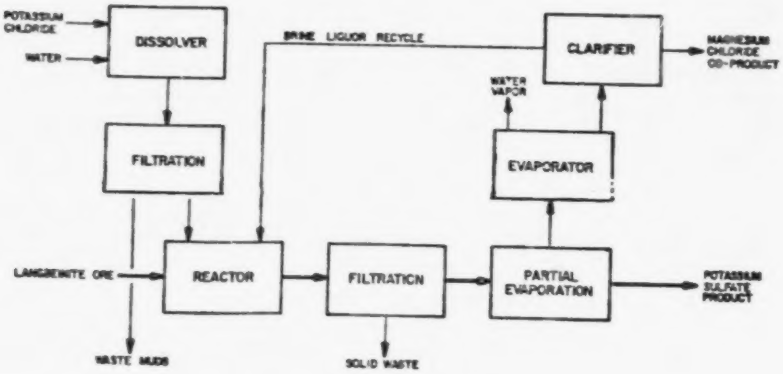
Water use at sylvinite ore processing facilities is shown as follows:

	l/kkg of product (gal/ton)	
Facility	5838	5843
input:		
fresh water	6,420 (1,540)	1,750 (421)
brine	not known	3,160 (760)
use:		
process contact	34,600 (8,300)	11,900 (2,900)
cooling	0	0
boiler feed	0	205 (50)
consumption:		

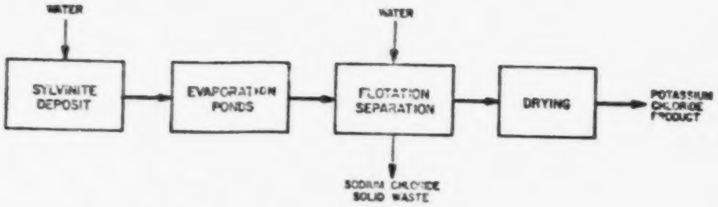
FIGURE 30


BRINE
BRINE RECYCLE
WATER
FLOTATION CHEMICALS
VENT
ORE
CRUSH AND GRIND
DESLIME AND SEPARATE
FLOTATION
DEWATER
DRY
SCREEN
PRODUCT
BRINES TO WASTE OR TO RECYCLE
SLIMES TO WASTE
TAILINGS WASTE AND BRINE
LEGEND:
ALTERNATE ROUTES

POTASSIUM CHLORIDE MINING AND PROCESSING FROM SYLVINITE ORE


POTASSIUM CHLORIDE
WATER
DISSOLVER
BRINE LIQUOR RECYCLE
CLARIFIER
MAGNESIUM CHLORIDE CO-PRODUCT
WATER VAPOR
FILTRATION
EVAPORATOR
LANGBEINITE ORE
REACTOR
FILTRATION
PARTIAL EVAPORATION
POTASSIUM SULFATE PRODUCT
WASTE MUDS
SOLID WASTE

LANGBEINITE MINING AND PROCESSING


WATER
WATER
SYLVINITE DEPOSIT
EVAPORATION PONDS
FLOTATION SEPARATION
DRYING
POTASSIUM CHLORIDE PRODUCT
SODIUM CHLORIDE SOLID WASTE

POTASH RECOVERY BY SOLUTION MINING OF SYLVINITE

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process waste	6,420 (1,540)	4,710 (1,130)
boiler blowdown	0	205 (50)

Water use at langbeinite ore processing facilities is shown as follows:

	l/kkg of product (gal/ton)	
Facility	5813	5822
input:		
fresh water	8,360 (2,000)	4,800 (1,200)
use:		
leaching and washing	5,000 (1,200)	4,800 (1,200)
cooling	30,000 (7,200)	0
consumption:		
process evaporation	0-1,670 (400)	0
process waste	0-1,670 (400)	4,800 (1,200)
cooling water evaporation	6,700 (1,600)	0

For sylvinite ore processing, the raw wastes consist largely of sodium chloride and insoluble impurities (silica, alumina, etc.) present in the ore. In langbeinite processing the wastes are insolubles and magnesium chloride. A comparison of the raw wastes of two sylvinite facilities (facilities 5838 and 5843) with langbeinite raw wastes (facilities 5813 and 5822) is given below. Differences in ore grades account for differences in the clay and salt wastes:

	kg/kkg of product (lb/1000 lb)	
Facility	5838	5843
wastes:		
clays	75	235
NaCl (solid)	3,750	2,500
NaCl (brine)	1,400	1,000
KCl (brine)	75	318
$MgSO_4$	640	75
K_2SO_4	440	0
Facility	5813	5822

A small percentage of the wastes of facility 5838 is sold. Part of the magnesium chloride from langbeinite processing is periodically recovered for sale and part of the remaining brine solution is recycled as process water.
These brines contain about 33 percent solids.
The wastes consist of muds from the ore dissolution and the

wasted brines.
The latter brine can sometimes be used for $MgCl_2$ production if high grade, low sodium content langbeinite ore is used. The composition of the brines after K_2SO_4 recovery is:

potassium	3.29%
sodium	1.3%
magnesium	5.7%
chloride	18.5%
sulfate	4.9%
water	66.7%

UTAH OPERATIONS

Solution mining of sylvinite is practiced at two facilities in Utah. The sylvinite (NaCl, KCl) is solution mined, and the resulting saturated brine drawn to the surface is evaporated to dryness in large surface ponds. The dried recovered material is then harvested from the ponds and separated by flotation into sodium and potassium chlorides. The sodium chloride tailings are discarded as a waste and the recovered potassium chloride is then dried and packaged. A process flowsheet is given in Figure 30.

Fresh water is used for process purposes at facility 5998 in the following amounts: 10,600,000 l/day (2.8 mgd) and 11,700 l/kkg (2,800 gal/ton). Water is used first in the flotation circuit and then in the solution mining. The resulting brine from these operations is evaporated and then processed in the flotation unit. There is no discharge of process water.

TRONA (SIC 1474)

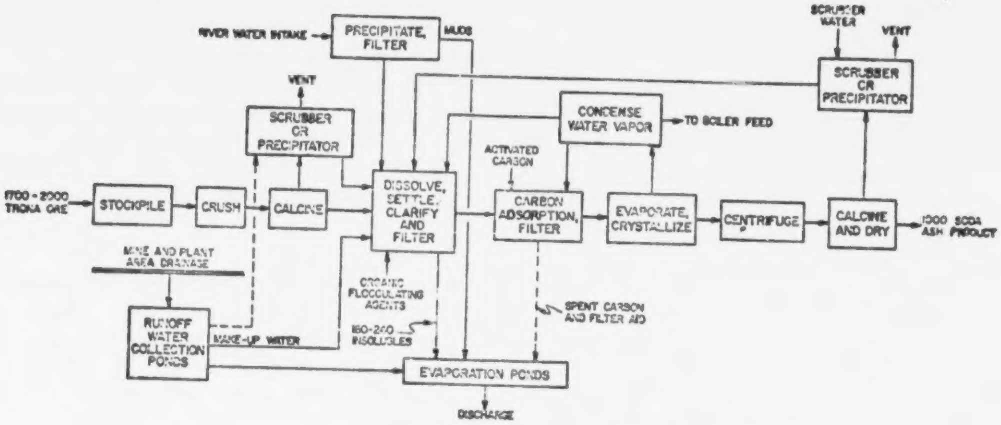
All U.S. mining of trona ore (impure sodium sesquicarbonate) is carried out in Sweetwater County, Wyoming, in the vicinity of Green River. The deposits are worked at four facilities. Three mine trona ore and process it to the pure sodium carbonate (soda ash). One of these three facilities also produces other sodium salts using soda ash as a raw material. The fourth facility has only mining operations at this time, but plans to build a soda ash processing facility on the site in the near future. The 1973 production of soda ash from these deposits amounted to 3,100,000 kkg (3,400,000 tons). This corresponds to about 5,800,000 kkg of trona ore mined (6,500,000 tons).

The facility data contained herein are current except for facilities 5962 and 5976 which are appropriate to the 1971 period when the discharge permit applications were processed. The trona ore mining rate in 1971 was approximately 4,000,000 kkg/yr (4,400,000 tons/yr). Rapid expansion in capacity of these facilities has been taking place in recent years and continues at this time. Since the mining and ore processing operations are integrated at these facilities, they are covered as a whole by this analysis. All four facilities are represented in the data.

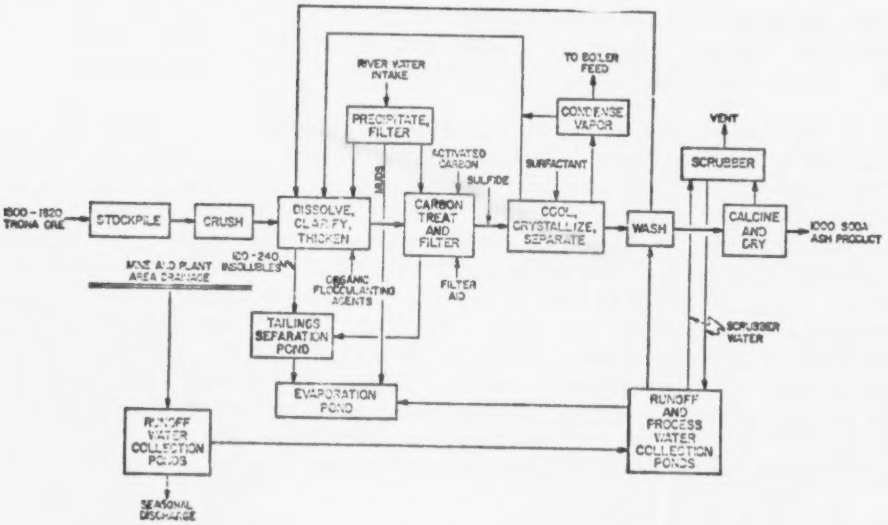
The trona deposits lie well beneath the surface of this arid region and are worked by room and pillar mining or longwall mining at depths of 240 to 460 m (800 to 1500 ft). The broken ore is transported to the surface and stockpiled for further processing. The mining is a dry operation except for leakage from overlying strata through which the mine shafts were sunk or from underlying strata under pressure. All four facilities experience such mine leakage.

The on-site refining process for trona ore consists of its conversion to the pure sodium carbonate, called "soda ash". The processing includes the removal of insoluble impurities through crushing, dissolving and separation, removal of organic impurities through carbon absorption, removal of excess carbon dioxide and water by calcining and drying to soda ash. Two variations of the process are used, the "sesquicarbonate" process and the "monohydrate" process. At present all three soda ash refineries use the monohydrate process. One also uses the sesquicarbonate process. General process flow diagrams of both processes are shown in Figure 31 with the raw materials and principal products material balances given in units of kg/kkg soda ash product.

FIGURE 31


RIVER WATER INTAKE
PRECIPITATE, FILTER
MUDS
SCRUBBER WATER
VENT
SCRUBBER OR PRECIPITATOR
VENT
SCRUBBER OR PRECIPITATOR
CONDENSE WATER VAPOR
TO BOILER FEED
ACTIVATED CARBON
1700 - 2000 TRONA ORE
STOCKPILE
CRUSH
CALCINE
DISSOLVE, SETTLE, CLARIFY AND FILTER
CARBON ADSORPTION, FILTER
EVAPORATE, CRYSTALLIZE
CENTRIFUGE
CALCINE AND DRY
1000 SODA ASH PRODUCT
MINE AND PLANT AREA DRAINAGE
ORGANIC FLOCCULATING AGENTS
SPENT CARBON AND FILTER AID
RUNOFF WATER COLLECTION PONDS
MAKE-UP WATER
160-240 INSOLUBLES
EVAPORATION PONDS
DISCHARGE

TRONA ORE PROCESSING
BY THE MONOHYDRATE PROCESS


RIVER WATER INTAKE
TO BOILER FEED
PRECIPITATE, FILTER
CONDENSE VAPOR
VENT
ACTIVATED CARBON
MUDS
SURFACTANT
SCRUBBER
SULFIDE
1800 - 1920 TRONA ORE
STOCKPILE
CRUSH
DISSOLVE, CLARIFY, THICKEN
CARBON TREAT AND FILTER
COOL, CRYSTALLIZE, SEPARATE
WASH
CALCINE AND DRY
1000 SODA ASH PRODUCT
120 - 240 INSOLUBLES
MINE AND PLANT AREA DRAINAGE
ORGANIC FLOCCULATING AGENTS
FILTER AID
TAILINGS SEPARATION POND
SCRUBBER WATER
EVAPORATION POND
RUNOFF AND PROCESS WATER COLLECTION PONDS
RUNOFF WATER COLLECTION PONDS
SEASONAL DISCHARGE

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TRONA ORE PROCESSING
BY THE SESQUICARBONATE PROCESS

These processes both require large quantities of process and cooling water for efficient operation, but the arid climate in this area (average annual precipitation of 7 to 8 inches) allows for disposal of waste water through evaporation in ponds.

Raw wastes from these operations come from three sources: mine pumpout water, surface runoff and ground water, and ore processing water. The wastes in the mine and surface water are principally saline materials (dissolved solids) and suspended solids. The ore processing raw wastes are principally the impurities present in the trona ore plus some unrecovered sodium carbonates, carbon, filter aids, and treatment chemicals as well as any minerals entering with the makeup water. The average mine pumpout at these facilities ranges from less than 19 to 1,140 l/min (5 to 500 gpm).

waste materials (mg/l)	5962	5976
dissolved solids	74,300	11,500
suspended solids	369	40
COD	346	2.1
ammonia		8.1
fluoride		11
lead		0.023
chloride		1,050
sulfate		655

High ground water levels during the March through August period give a seasonal water flow in the 5962 facility containing 2,160 kg/day (4,750 lb/day) of total solids, principally dissolved solids. This particular ground water problem apparently does not exist at the other facilities. Rainwater and snow runoff discharges are highly variable and also contain saline dissolved solids and suspended solids.

Unlike the foregoing wastes, the ore processing wastes are principally related to the production rate and, hence, are given on the basis of a unit weight of ore:

waste material	kg/kkg of ore (lb/1000 lb)
ore insolubles (shale and shortite)	100-140
iron sulfide (FeS)	0-1
sodium carbonate	60-130
spent carbon and filter aids (e.g., diatomaceous earth, perlite)	0.5-2

The composition of the mill tailings water flow from facility 5933 to the evaporation ponds, is:

total dissolved solids:	15,000 mg/l
total suspended solids:	2,000 mg/l
total volatile solids:	2,500 mg/l
chloride:	3,400 mg/l

Water use at the mines having attached refineries is determined principally by the refining process. The only water associated with the mines is mine pumpout, dust control water and sewage, the latter two being rather small.

Relative flow per unit production values for the mine pumpout are not useful since the flow is not influenced by production rate. There are three major routes of consumption of the water taken into these facilities: evaporation in the course of refining via drying operations and cooling water recycling, discharge of waste water to evaporation ponds (both process and sanitary), and by discharge of wastes to waterways. The consumption of water for the three soda ash refiners via these routes is:

total consumption	10^6 l/day (mqd)	l/kkg of product (gal/ton)
average	9.3	2,840 (680)
range of averages	7.08-10.6 (1.9-2.8)	2,250 - 3,200 (540-760)
evaporation in processing		
average	3.4 (0.9)	1,100 (260)
range of averages	3.0-3.8 (0.8-1.0)	940 - 1,200 (230-280)
net flow to evaporation ponds		
average	5.8 (1.5)	1,800 (430)
range of averages	4.1-6.8 (1.1-1.8)	1,300 - 2,000 (320-490)
discharge		
average	23,000 (0.006)	8 (2)
range of averages	0-45,000 (0-0.012)	0-13 (0-3)

A significant variation in the above flows during the course of a year would be the effect of increase in production rate occasioned by a facility expansion.

SODIUM SULFATE (SALT CAKE)

Sodium sulfate (salt cake) is produced from natural sources in three different geographical areas by three different processing methods because of differences in the ores or brines utilized. Salt cake is also recovered as a by-product of numerous inorganic chemical industry processes. The three mining processes are:

(a) Recovery from Great Salt Lake brines as part of a stepwise evaporation process. Sodium chloride and potassium sulfate are recovered as co-products. This process was discussed in Salines from Brine Lakes.
(b) Recovery from Searles Lake brines as part of an involved evaporative series of processes which generate 13 products. This process was also discussed in Salines from Brine Lakes.
(c) Recovery from West Texas brines by a selective crystallization process.

There are two facilities mining sodium sulfate from brine wells. Sodium sulfate natural brines are pumped from wells, settled to remove suspended muds and then saturated with salt (NaCl). The brine mixtures are cooled to precipitate sodium sulfate. The precipitated solids are recovered by filtration and the spent brine is fed to an evaporation pond as a waste. The recovered solids are melted, calcined to effect dehydration, cooled and packaged. A process flowsheet is shown in Figure 32.

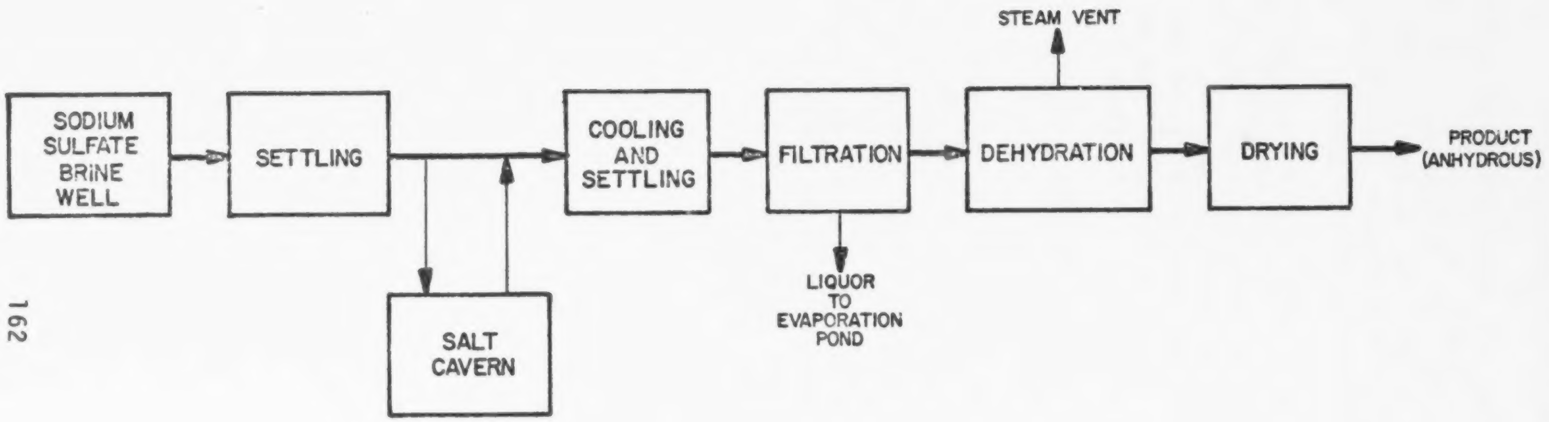

SODIUM SULFATE BRINE WELL
SETTLING
SALT CAVERN
COOLING AND SETTLING
FILTRATION
LIQUOR TO EVAPORATION POND
DEHYDRATION
STEAM VENT
DRYING
PRODUCT (ANHYDROUS)

FIGURE 32
SODIUM SULFATE FROM BRINE WELLS

ROCK SALT (SIC 1476)

There are approximately 21 producers of rock salt in the United States. Eleven facilities were visited representing over 90 percent of the salt production. The operations and the type of waste generated are similar for the entire industry. The sources of waste and the methods of disposition vary from facility to facility. This study covers those establishments engaged in mining, crushing and screening rock salt.

The salt is mined from a salt dome or horizontal beds at various depths by conventional room and pillar methods. The face of the material is undercut, drilled and blasted and the broken salt passed through a multiple stage crushing and screening circuit. The products normally 1" and smaller are hoisted to the surface for further screening and sizing and preparation for shipment. The extent of the final crushing and screening carried out on the surface varies and in some cases practically all is done underground. See Figure 33 for a typical process flow diagram.

The waste water from these salt facilities consists primarily of a salt solution of varying sodium chloride content and comes from one or more of the following sources:

(1) Wet dust collection in the screening and sizing steps,

(2) Washdown of miscellaneous spills in the operating area and dissolving of the non-salable fines,

(3) Mine seepage.

(4) Storage pile runoff.

In the mining and processing of rock salt, water consumption is variable due to the miscellaneous nature of its use. Routine use is for cooling, boilers (heating) and sanitation with a small volume consumed in the process for dissolving anti-caking reagents. Variable volumes are used in dust collection and washdown of waste salt including non-salable fines from the operating areas.

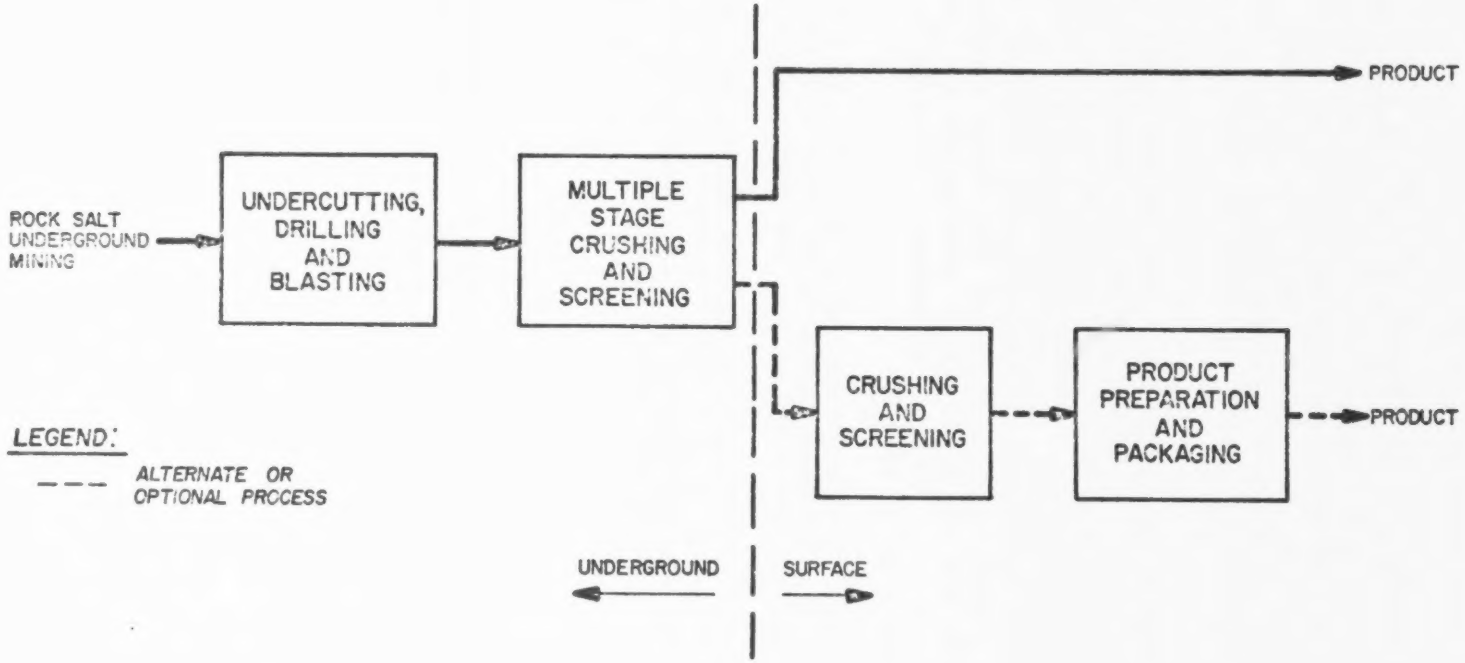

ROCK SALT UNDERGROUND MINING
UNDERCUTTING, DRILLING AND BLASTING
MULTIPLE STAGE CRUSHING AND SCREENING
PRODUCT
CRUSHING AND SCREENING
PRODUCT PREPARATION AND PACKAGING
PRODUCT
LEGEND:
– – – ALTERNATE OR OPTIONAL PROCESS
UNDERGROUND
SURFACE

FIGURE 33
ROCK SALT MINING AND PROCESSING

PHOSPHATE ROCK (SIC 1475)

Phosphate ore mining and processing is carried out in four different regions of the United States. These areas and their contribution to the total output are Florida, 78%; Western states, 12%; North Carolina, 5%; and Tennessee, 5%. Eighteen to twenty different companies with about 25 to 30 operations account for greater than 95 percent of the output. Data collected through visits to most of the operating facilities are analyzed in this section.

Eighty-three percent of the ore is processed by flotation. The major wastes associated with phosphate production are the slimes and flotation tailings which consist primarily of clays and sands. These are separated from the phosphate rock through various processing techniques such as grinding, screening, crushing, classification, and finally, desliming or a combination of desliming and flotation. The method of processing does merit subcategorization in that economics can preclude the extensive use of recycled water in flotation processing.

FLOTATION

The flotation operations include all in Florida and North Carolina and one in Utah. The ore which lies at varying depths from the surface is mined from open pits by use of draglines and dumped into pits adjacent to the mining cut. The material is slurried with the use of high pressure streams of water from hydraulically operated guns and pumped to the beneficiation facility where it enters the washer section. This section separates the pebble phosphate rock from the slurry which is accomplished by a series of screening, scrubbing and washing operations. The coarse fraction termed pebble is transferred to product storage and the fine phosphatic material is collected and pumped to surge bins for further processing.

The next step in the process is the removal by cyclones of the -150 mesh fraction referred to as slimes, colloidal clays and very fine sands, which are pumped to settling ponds. The oversize material is transferred to the flotation section, where it is conditioned for the first stage flotation. The floated material may be stored "as is" or de-oiled, conditioned and directed to a second stage flotation. The phosphate rock product is dried and stored. The tailings (sands) from the flotation steps are discharged as a slurry to mined out areas for land reclamation.

Facility 4022 is the only Western facility that includes a flotation step. After the cycloning or desliming step, the material is fed to a flotation circuit consisting of conditioning with rougher and cleaner cells. The flotation tailings are combined with slimes and thickened prior to being discharged to the settling pond.

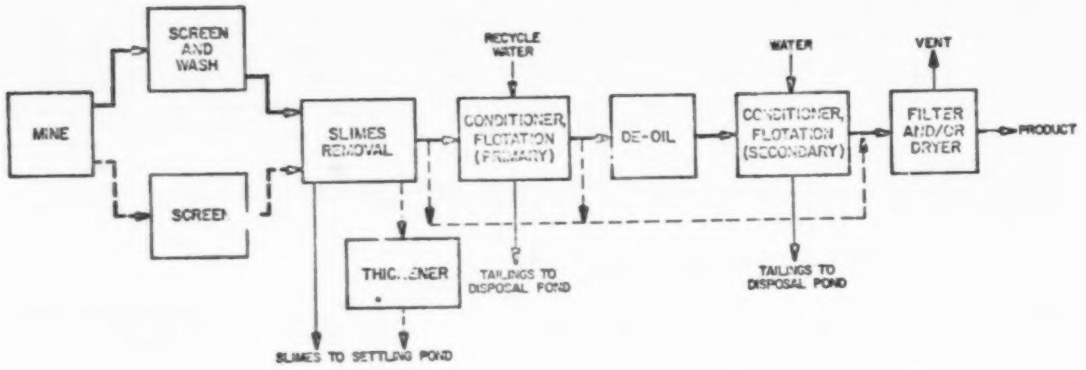
Facility 4003 differs in processing from the general description in the first part of the mill operation. The ore feed slurry is passed through a multiple stage screening step separating the -14 mesh for flotation and the oversize is discarded. The mine operation is unique in that the ore lies some 30 m (100 ft) below the surface. To maintain a dry pit, it is necessary to de-pressurize an underlying high yield artesian aquifer. This is accomplished through use of a series of deep well pumps surrounding the pit that removes sufficient water to offset the incoming flow refilling the zone. See Figure 34 for the process flow diagram of flotation operations.

Almost all water used in the beneficiation of phosphate ore is for processing purposes. Only minimal volumes are used for non-contact cooling and sanitary purposes. A typical usage is in the range of 41,000 l/kkg (10,000 gal/ton) of product with a considerable variation occurring within the various facilities. The wide range of water usage may be attributed to the operating procedures and practices, the weight recovery (product/ton of ore), the percent of ore feed processed through flotation, the ore characteristics, and the facility layout and equipment design.

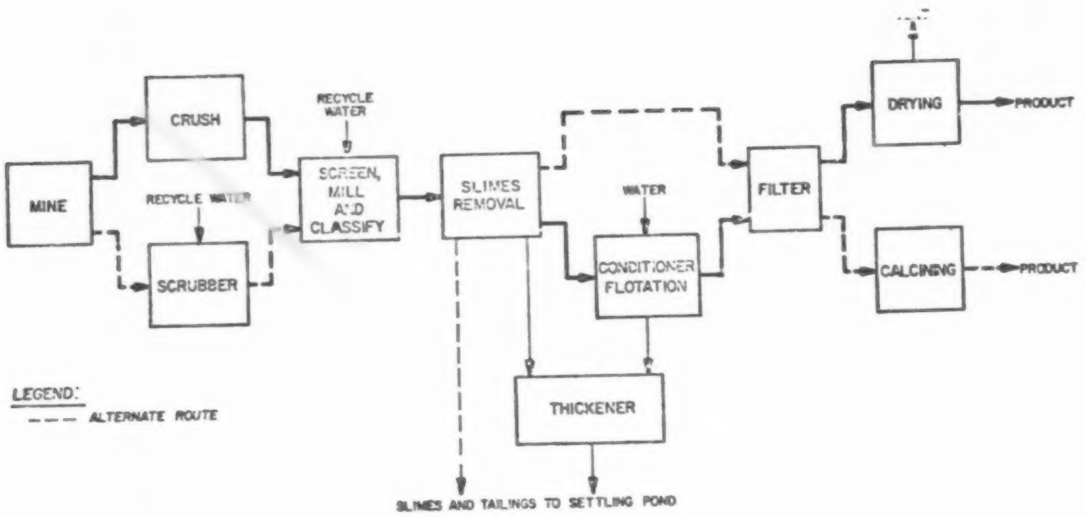
A comparison of water usage in the various facilities is as follows:

Facility	10^6 l/day	mgd	l/kkg	gal/ton	Percent Recycle
4002	248.1	65.5	25,800	6200	85
4003	411.4	108.7	45,300	10,900	60
4004a	205.9	54.4	Not Available		74
4004b	121.9	32.2	Not Available		74
4005a	246.5	65.0	18,100	4300	95
4005b	107.7	28.5	14,200	3400	95
4005c	370.9	98	30,600	7300	95
4007	none		none (mine only)		N/A
4015	313.0	82.7	45,500	10,900	90
4016	182.1	48.1	31,800	7600	84
4017	726.4	191.9	91,400	21,900	90
4018	358.2	94.6	66,600	15,900	N/A
4019a	355.0	93.8	64,300	15,400	N/A
4019b	573.8	151.6	78,000	18,700	N/A

FIGURE 34


MINE
SCREEN AND WASH
SCREEN
SLIMES REMOVAL
THICKENER
RECYCLE WATER
CONDITIONER, FLOTATION (PRIMARY)
DE-OIL
WATER
CONDITIONER, FLOTATION (SECONDARY)
VENT
FILTER AND/OR DRYER
PRODUCT
TAILINGS TO DISPOSAL POND
TAILINGS TO DISPOSAL POND
SLIMES TO SETTLING POND

PHOSPHATE MINING AND PROCESSING
EASTERN


MINE
CRUSH
RECYCLE WATER
SCRUBBER
RECYCLE WATER
SCREEN, MILL AND CLASSIFY
SLIMES REMOVAL
WATER
CONDITIONER FLOTATION
THICKENER
FILTER
DRYING
PRODUCT
CALCINING
PRODUCT
SLIMES AND TAILINGS TO SETTLING POND
LEGEND:
ALTERNATE ROUTE

PHOSPHATE MINING AND PROCESSING
WESTERN

4019c	255.9	67.6	81,100	19,400	N/A
4020a	257.4	68	21,300	5,100	80
4020b	174.1	46	32,200	7,700	85
4022			11,200	2,700	66

The sources of the process water consist primarily of recycle (from ponds) with additional makeup coming from wells and natural streams. Generally no additional treatment of the water is carried out prior to reuse.

The wastes associated with the various facilities and their quantities follow:

	kg/kkg (lb/1000 lb) of product			
Facility	Slimes	Tailings	Mine Pit Seepage	Dust Scrubber Slurry
4002	790	1380	yes	no
4003	370	840	yes	yes
4004a	information not available		yes	yes
4004b	information not available		yes	no
4005a	1180	900	yes	yes
4005b	1160	1290	yes	no
4007	no (a mine only)		runoff only	no
4005c	1050	1520	yes	yes
4015	1000	1000	yes	yes
4016	1300	1300	yes	yes
4017	860	2440	yes	yes
4018				
4019a	770	2140	yes	yes
4019b	900	2610	yes	yes
4019c	1290	2100	yes	yes
4020a	1030	1230	yes	yes
4020b	1330	1570	yes	yes
4022	1710		no	no

In addition to the slimes and tailings, facility 4003 disposes of about 120 kg/kkg product as solid waste from the initial stage of beneficiation.

WASHING

Facilities 4006, 4008 and 4025, located in Tennessee do not include the flotation step. The processing is complete after the washing and desliming stages and, in some cases, after a final filtering of the product. The locations of the mines are usually some distance from the beneficiation facility and the ore is brought in dry, as mined, by truck or rail.

The Western producers of phosphate rock contribute about 12 percent of the total U.S. production. All of the major operations in this geographical area were visited. They represent four companies and five different operating areas. The higher net evaporation rate is the major factor responsible for making it feasible to attain no discharge. Only one Western plant utilizes a flotation process.

The Western bedded and inclined ore deposits lie at varying depths and are mined by open pit methods. The mining methods generally involve the use of scrapers, rippers and/or drilling and blasting. The ore is transported to the facility area by truck or rail where it enters the first stage of beneficiation which consists of crushing and/or scrubbing. Subsequent sizing is accomplished through further crushing, grinding and classification, with the sized feed being directed to the desliming section for removal of the minus 325 material. These slimes are discharged either directly to a tailings pond or through a thickener. The underflow product from the desliming step is filtered. The filtered material may be further processed through a drying and/or calcining step prior to shipment. See Figure 34 for the process flow diagram. Facilities 4024 and 4030 do not beneficiate. The ore is mined and shipped to other locations for processing.

At all operations where ore beneficiation occurs, the process water recycle is 65 percent or greater. Most of the remaining percentage of water is tied into the settled slimes. The overflow from the settling pond is returned to the process. The water usage is almost totally for processing (>95 percent) with only a minimal volume used in other areas of the facility such as non-contact cooling and sanitary. A comparison of water usage in each facility is as follows:

Facility	l/kkg (gal/ton) Product	Percent Recycle	Makeup water Source
4006	20,400 (4,900)	0	
4008	18,400 (4,400)	66	
4025	25,500 (6,100)	80	
4023	3,500 (830)	60	wells
4029	5,000 (1,200)	66	wells
4031	8,300 (2,000)	75	wells

The raw wastes are the slimes from desliming cones. In the mining area of all facilities the only waste water occurring is normal surface runoff.

Facility	Slimes kg/kkg (lb/1000 lb) of Product
4006	1000
4008	580
4025	1010
4023	500
4029	484
4031	580

The disposition of the wastes from these facilities is to settling ponds. In the operations that have dryers and calciners, the dust from the scrubber system is discharged to the slimes waste stream.

SULFUR (FRASCH) (SIC 1477)

There are currently thirteen known significant U.S. Frasch sulfur facilities producing molten sulfur. Two of these facilities are located in anhydrite deposits and eleven on salt domes. Two of the salt-dome facilities are offshore operations. Only one of the offshore facilities is in production. The second facility will resume operation in 1975. All of these facilities are designed for a maximum hot water generation capacity. The sulfur-to-water ratio varies greatly from formation to formation, from location to location, and from time to time. The latter occurs because normally as a mine ages, the water to sulphur ratio increases. Therefore, the quantity of water used in this industry category is not determined solely by the quantity of product. More than 85 percent of the sulfur delivered to domestic markets remains as a liquid, from well to customer. Liquid shipments are made in heated ships, barges, tank cars and trucks. Molten sulfur is solidified in vats prior to shipment in dry form.

ANHYDRITE OPERATIONS

A Frasch installation starts with a borehole drilled by a conventional rotary rig to the top of cap rock. A steel casing is then lowered into the borehole. Drilling is then continued into the sulfur formation. A liner, which has two sets of perforations, is set from the surface into the sulfur formation. The first set of perforations is several feet from the bottom and the second set is about five feet above the first set. A second pipe, of smaller diameter, is placed inside the liner with the lower end open and a few inches above the bottom. A ring-shaped seal is placed around the smaller pipe between the two sets of perforations to close off the circulation in the annular space of the two concentric pipes.

Incoming water is treated either by hot lime or the cold clarification process plus softening, and a portion goes to the boilers. Steam from the boilers is used to superheat the remaining water. Superheated water, under pressure and at a temperature of about 163°C (325°F), is pumped down the annular space between the two pipes, and, during the initial heating period, down through the sulfur pipe. The hot water flows through the holes at the bottom into the sulfur-bearing deposit. As the temperature rises, the sulfur melts. Because the liquid sulfur is heavier than the water, it sinks to the bottom where it enters the lower liner perforations. Pumping water down the sulfur pipe is then discontinued. Following the direction of least pressure, the liquid sulfur moves up through the small pipe.

Its upward motion is aided by the introduction of compressed air through a one-inch pipe. After reaching the surface, the liquid sulfur is collected and pumped into steam-heated tanks or barges for direct shipment to the customer or it is transported to a shipping center.

In the start up of new and existing wells some hot water will preceed the upcoming sulfur and this water will be bled, in the case of estuary operations directly to surface waters. This is called sealing water. In addition to producing wells, "bleed-off" wells must be drilled in appropriate locations to control dome pressure and permit continuous introduction of hot water.

At facilities located in anhydrite deposits, the "bleed-off" water is heated and reused in the system. In general, 50 percent of the process water used in these facilities is recovered. The remainder is lost in the sulfur-bearing formation. At facilities located on salt domes, the "bleed-off" water is saline because of the association of the sulfur deposits with salt domes. The bleedwater is the major waste water of these facilities, since the water is too corrosive to reuse.

Removal of large quantities of sulfur from the formation increases the voids and cavities underground. Subsidence and resulting compaction eliminate most of these void spaces. Drilling muds are also used to fill some of the areas already mined. Some of these facilities mix the sludge generated from their water softening and treating operation with clay and use it as a substitute drilling mud. Generalized process diagrams for mines located in an anhydrite deposit and in salt domes are given in Figure 35.

The process raw waste consists of the sludge (primarily $CaCO_3$) which originates from the water purification operation. The raw waste loads are presented as follows:

Waste Material at Facility	kg/kkg of product (lb/1000 lb) 2020	2095
Water softener sludge	9.6	15.3

Facility 2020 consumes water at an average of 6,970 l/kkg (1,670 gal/ton) of product, 50 percent of which is recycled back to the system and the remainder is lost in the sulfur-bearing formation. This includes about 5 liters of non-contact cooling water per kkg (1.3 gal/ton) of product used in their compressor circuit. Facility 2095 uses on the average 8,470 l/kkg (2,030 gal/ton) of product. It recovers 40-60 percent of this water from its bleedwells.

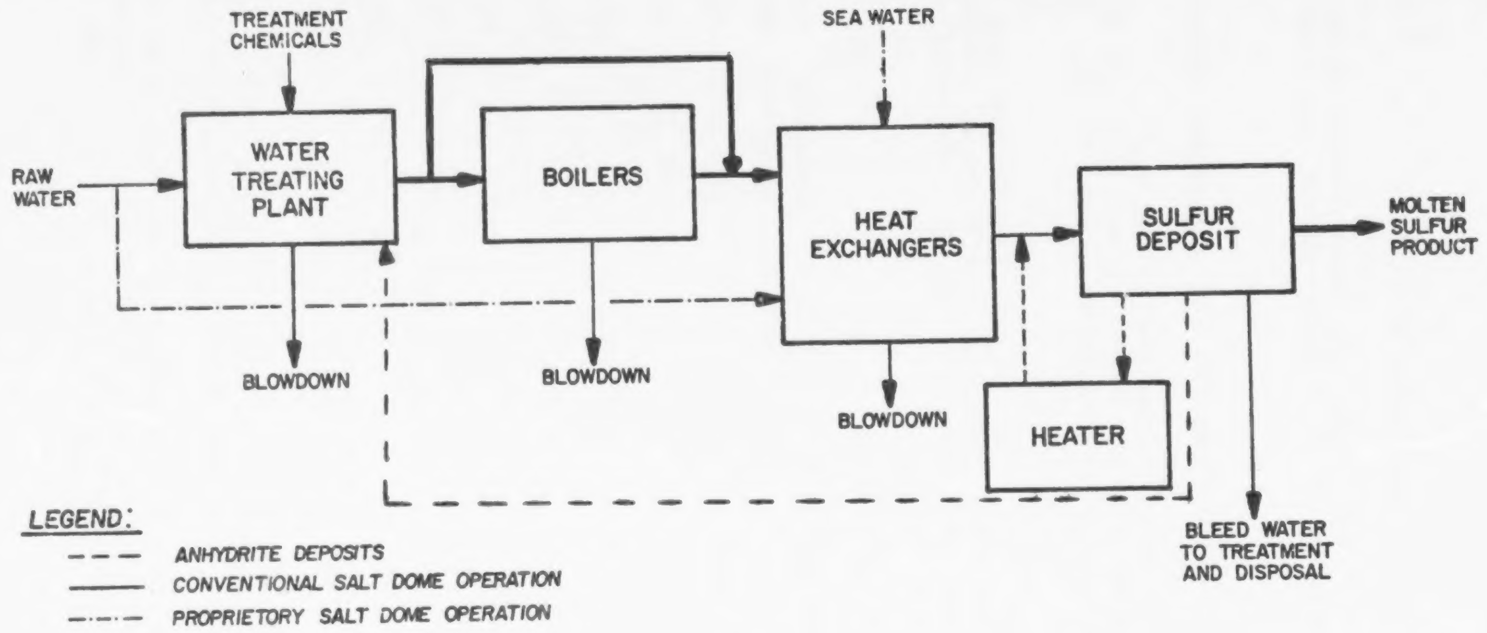

TREATMENT CHEMICALS
SEA WATER
RAW WATER
WATER TREATING PLANT
BOILERS
HEAT EXCHANGERS
SULFUR DEPOSIT
MOLTEN SULFUR PRODUCT
BLOWDOWN
BLOWDOWN
BLOWDOWN
HEATER
BLEED WATER TO TREATMENT AND DISPOSAL
LEGEND:
ANHYDRITE DEPOSITS
CONVENTIONAL SALT DOME OPERATION
PROPRIETORY SALT DOME OPERATION

FIGURE 35

SULFUR MINING AND PROCESSING
(FRASCH PROCESS)

SALT DOME OPERATIONS

The process is the same as that described in Anhydrite Operations. Raw wastes from these operations come from five sources:

(a) bleed water,
(b) sludge from water treating and softening operations,
(c) surface runoff,
(d) mining water used in sealing wells, and
(e) miscellaneous sanitary waste, power facility area waste, cooling water, boiler blowdown, steam traps, and drips and drains.

The bleedwater from the mines is saline and contains dissolved solids which have a high content of sulfides. Its quantity and chemical composition is independent of the sulfur production rate.

Data on bleedwater follows:

Plant	liters/day (MGD)	TSS mg/liter	sulfide mg/liter	chloride mg/liter
2021	74,000,000 (19.5) (1)	<5	600 - 1,000	38,500
2022	18,000,000 (4.7)	<5	600 - 1,000	31,500
2023	428,000,000 (113.0) (2)	<5	600 - 1,000	59,200
2024	19,000,000 (5.0)	<5	600 - 1,000	14,600
2025	38,000,000 (10.0)	39	84	25,400
2026	17,000,000 (4.5)	--	--	--
2027	23,000,000 (6.0)	--	1,050	23,000
2028	11,500,000 (3.0)	--	--	--

(1) Includes 69,400,000 liters per day (18.3 MGD) of seawater used in final dilution and treatment step.

(2) Includes power plant discharge, sludge from hot lime water softening process, miscellaneous drips and drains and 401,000,000 liters per day (106 MGD) of seawater used in final dilution and treatment step.

The sludge from the water treating operations varies in chemical composition and quantity depending on the type of water used in the process. In some facilities, only drinking water and a small part of process water is softened and sea water constitutes the remainder of the process water. In other facilities, fresh water is used as process water and a portion of the facility water is softened by hot lime process prior to usage.

Information on runoff was obtained from four facilities. The runoff values given below are based on a one-inch rain and 100 percent runoff. The average yearly rainfall for these areas is estimated to be 54 inches. Information on sealing well water was available for facilities 2021 and 2024. In some facilities this waste is separate from their bleedwater waste stream and in others separate from the facilities miscellaneous wastes.

Facility	2021	2024
Flow, l/day(gal/day)	5,700 (1,500)	18,900 (5,000)
pH	7.9	7.5
TSS, mg/l	62	20
Sulfide, mg/l	7.8	57.2
BOD, mg/l	3.3	8.1
COD, mg/l	219	42

The waste stream for facility 2021 includes miscellaneous treated sanitary waste, drips and drains.

MINERAL PIGMENTS (IRON OXIDES) (SIC 1479)

The category "mineral pigments" might be more directly classified as "iron oxide pigments" as they are the only natural pigment mining and processing operations found. The quantity of natural iron oxide pigments sold by processors in the United States in 1972 was just under 63,500 kkg (70,000 tons).

One minor and two larger processors of natural iron oxide pigments were contacted. These three companies account for approximately 20 percent of the total U.S. production.

Iron oxide pigments are mined in open pits using power shovels or other earth removing equipment. At some locations these materials are a minor by-product of iron ore mined primarily for the production of iron and steel. Some overburden may be removed in mining.

Two processes are used, depending on the source and purity of the ore. For relatively pure ores, processing consists simply of crushing and grinding followed by air classification. A drying step can be included (facility 3019). Facility 3022 and facility 3100 are dry operations. Alternatively, for the less pure ores, a washing step designed to remove sand and gravel, followed by dewatering and drying is used (facility 3022). Solid wastes and waste waters may be generated in this latter process. These processes are shown in Figure 36.

In the wet processing of iron oxide for pigment, approximately 27,800 l/kkg product of water (6670 gallons/ton) is used (facility 3022). This process water is obtained from a large settling pond with no additional treatment. Approximately 95 percent of this water (26,400 l/kkg of product or 6,330 gal/ton) overflows from the rake thickener, and drains to the settling pond, while the remaining 5 percent (1,400 l/kkg or about 340 gal/ton) is evaporated on the drum dryer.

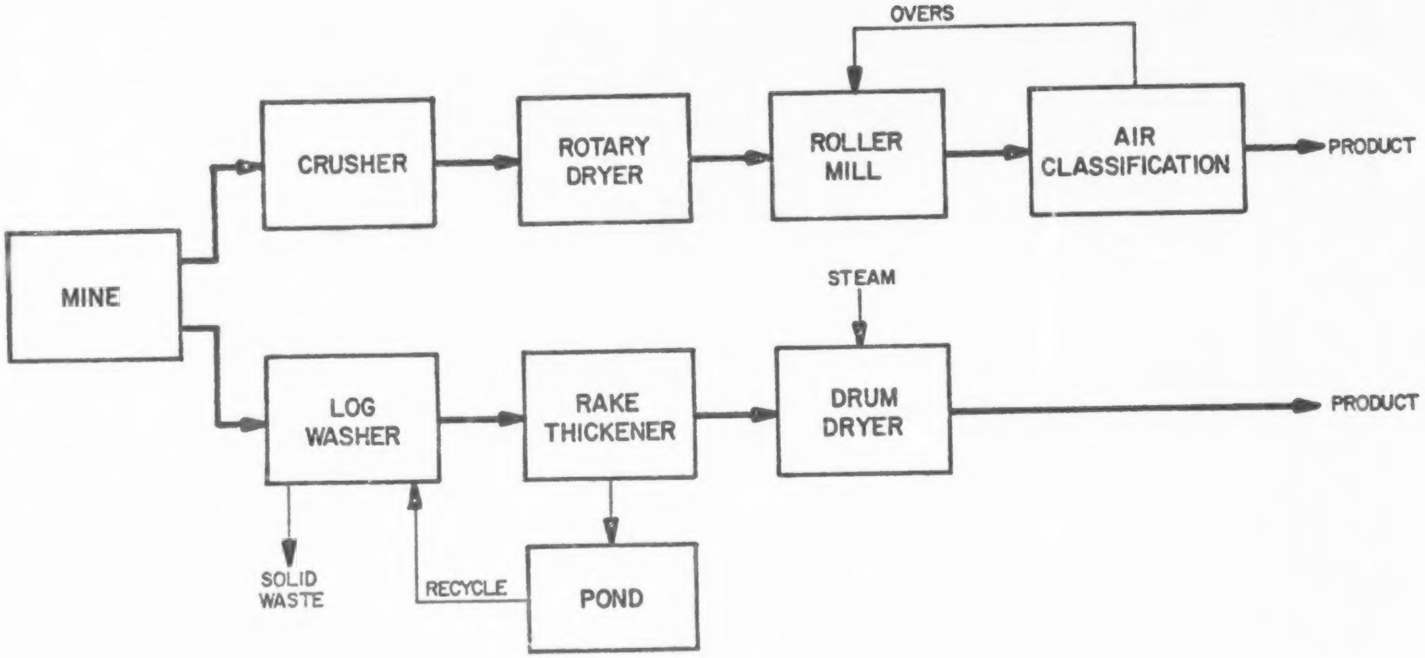

OVERS
CRUSHER
ROTARY DRYER
ROLLER MILL
AIR CLASSIFICATION
PRODUCT
MINE
STEAM
LOG WASHER
RAKE THICKENER
DRUM DRYER
PRODUCT
SOLID WASTE
RECYCLE
POND

FIGURE 36
MINERAL PIGMENT MINING AND PROCESSING

LITHIUM MINERALS (SIC 1479)

There are two producers of lithium minerals, excluding brine operations, and both sources are from spodumene ore which is separated from pegmatite ores by flotation. The method of concentrating the spodumene and the handling of the waste generated are very similar for both facilities.

The spodumene ore is produced from an open pit using conventional methods of mining. The ore is sized for flotation by passing through a multiple stage crushing system and then to a wet grinding mill in closed circuit with a classification unit. The excess fines in the ground ore, the major waste component, are separated through the use of cyclones and discharged to a settling pond. The coarse fraction is conditioned through the addition of various reagents and pumped to the flotation circuit where the spodumene concentrate is produced. This primary product, dependent upon the end use, is either filtered or dried. The tailings from the spodumene flotation circuit which consists primarily of feldspar, mica and quartz are either discharged to the slimes-tailings pond or further processed into salable secondary products and/or solid waste. The secondary processing consists of flotation, classification and desliming. The waste generated in this phase of the operation is handled similarly to those in the earlier steps of the process. A generalized diagram for the mining and processing of spodumene is given in Figure 37.

Reagents used in these facilities are: fatty acids; amines; hydrofluoric acid; sulfuric acid; and sodium hydroxide and other anionic collectors. The flocculants used for waste settling are alum and anionic-cationic polymers.

The two waste streams common to both facilities are the slimes-tailings from the flotation process and the mine pumpout. The volume of waste from the process being discharged as a slurry to the settling pond or stored as dry solids is directly related to the quantity of secondary products recovered. An additional waste stream which is unique to facility 4009 arises from the scrubbing circuit of the low iron process which removes certain impurities from a portion of the spodumene concentrate product. Information on the wastes from each facility is as follows:

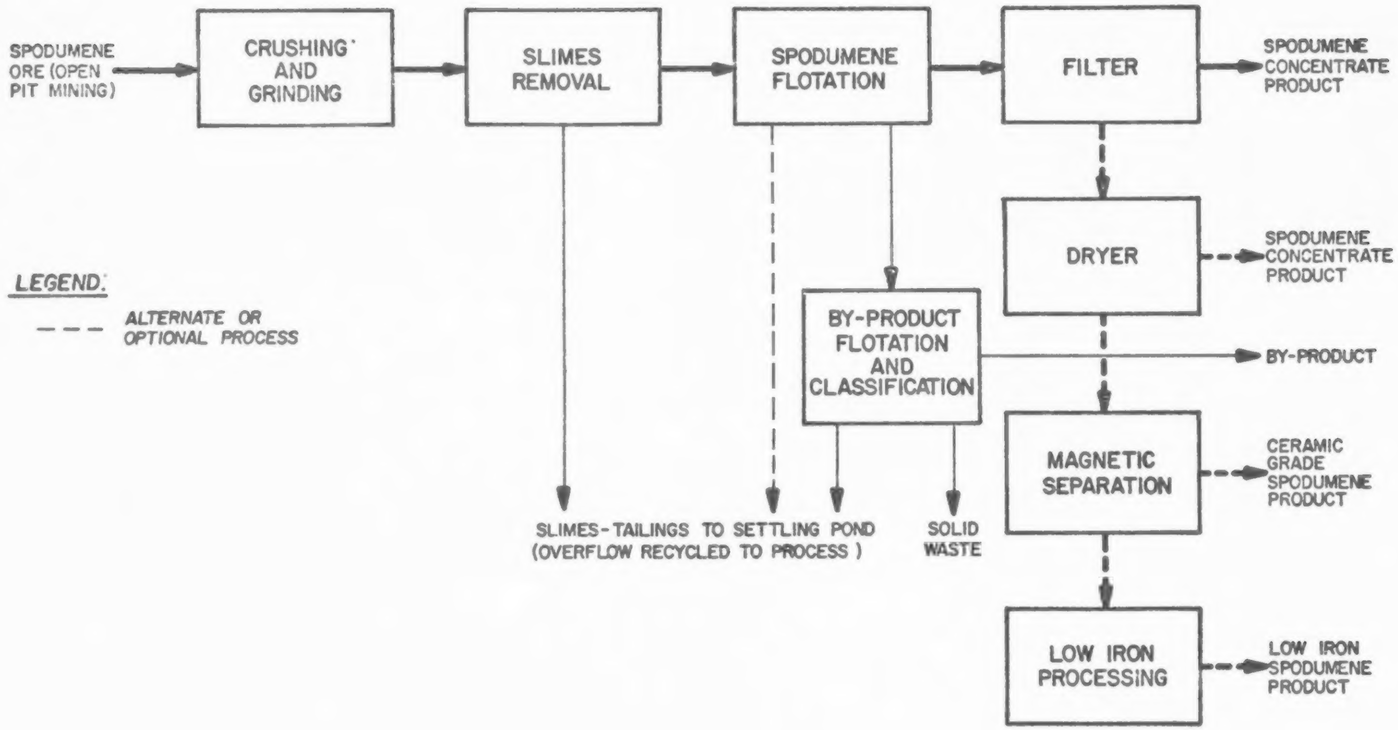

SPODUMENE ORE (OPEN PIT MINING)
CRUSHING AND GRINDING
SLIMES REMOVAL
SPODUMENE FLOTATION
FILTER
SPODUMENE CONCENTRATE PRODUCT
DRYER
SPODUMENE CONCENTRATE PRODUCT
BY-PRODUCT FLOTATION AND CLASSIFICATION
BY-PRODUCT
MAGNETIC SEPARATION
CERAMIC GRADE SPODUMENE PRODUCT
LOW IRON PROCESSING
LOW IRON SPODUMENE PRODUCT
SLIMES-TAILINGS TO SETTLING POND (OVERFLOW RECYCLED TO PROCESS)
SOLID WASTE
LEGEND:
– – – ALTERNATE OR OPTIONAL PROCESS

FIGURE 37
SPODUMENE MINING AND PROCESSING
(FLOTATION PROCESS)

Facility 4001

Waste Material	Source	kg/kkg of feed (lbs/1000 lb)
Slimes	flotation	100
Tailings	dewatering	unknown
Mine water	mine pit	(intermittent, unknown)

Facility 4009

Waste Material	Source	kg/kkg of feed (lbs/1000 lb)
Slimes & tailings	flotation	620
Mine water	mine pit	568,000 l/day (0.15 mgd) est.
Scrubber slurry	Low iron process	95,000 l/day (0.025 mgd) est.

At both facilities the process water recycle is 90 percent or greater. With the exception of the above mentioned scrubber slurry, the process waters are discharged to a settling pond where a major part of the overflow is returned for re-use. A breakdown of water use at each facility follows.

Facility 4001

1. Water Usage

	l/kkg of ore (gal/ton)	Water Source	Recycle
Process	12,500 (3,000)	a) Settling pond overflow b) Mine pumpout c) Well	95
Non-contact cooling	250 (60)	Well	100
Total	12,750 (3,060)		
2. Water Recycled	12,100 (2,900)		

Facility 4009

1. Water Usage

	l/kkg of ore (gal/ton)	Water Source	Recycle
Process	26,900 (6,450)	a) Settling pond overflow b) Creek	90
Non-contact cooling	1) 380 (90)	a) Settling pond overflow b) Creek	90
	2) 270 (60)	Municipal	0
Boiler	40 (10)		
Sanitary	190 (50)	Municipal	0
Total	27,780 (6,660)		

2. Water Recycled 24,600 (5,900)

BENTONITE (SIC 1452)

Bentonite is mined in dry, open pit quarries. After the overburden is stripped off, the bentonite ore is removed from the pit using bulldozers, front end loaders, and/or pan scrapers. The ore is hauled by truck to the processing facility. There, the bentonite is crushed, if necessary, dried, sent to a roll mill, stored, and shipped, either packaged or in bulk. Dust generated in drying, crushing, and other facility operations is collected using cyclones and bags. In facility 3030 this dust is returned to storage bins for shipping. A general process flowsheet is given in Figure 38.

There is no water used in the mining or processing of bentonite. Solid waste is generated in the mining of bentonite in the form of overburden, which must be removed to reach the bentonite deposit. Solid waste is also generated in the processing of bentonite as dust from drying, crushing, and other facility operations.

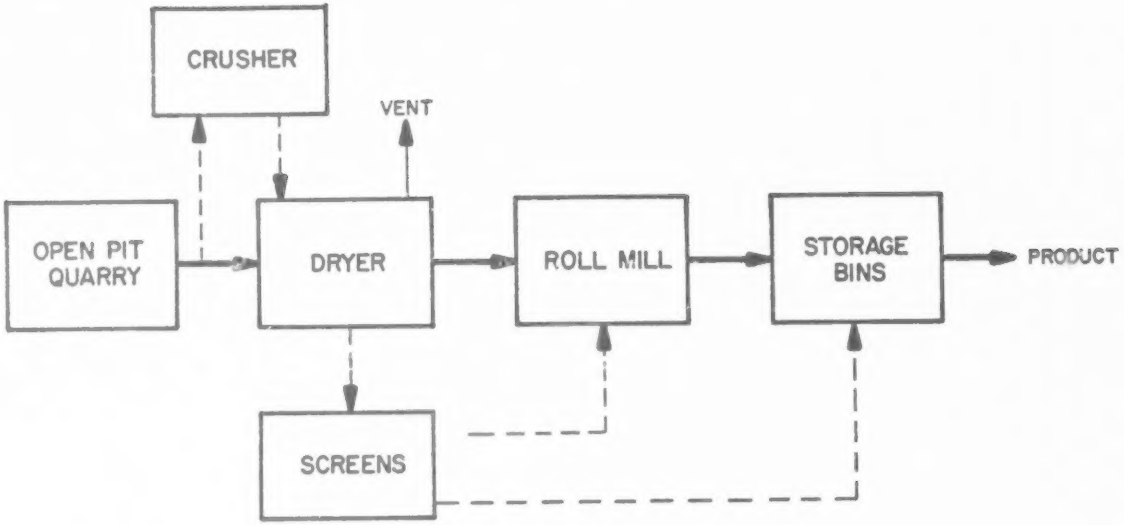

CRUSHER
VENT
OPEN PIT QUARRY
DRYER
ROLL MILL
STORAGE BINS
PRODUCT
SCREENS

FIGURE 38
BENTONITE MINING AND PROCESSING

FIRE CLAY (SIC 1453)

Fire clay is principally kaolinite but usually contains other minerals such as diaspore, boehmite, gibbsite and illite. It can also be a ball clay, a bauxitic clay, or a shale. Its main use is in refractory production. Fire clay is obtained from open pits using bulldozers and front-end loaders. Blasting is occasionally necessary for removal of the hard flint clay. The clay is then transported by truck to the facility for processing. This processing includes crushing, screening, and other specialized steps, for example, calcination. There is at least one case (facility 3047) where the clay is shipped without processing. However, most of the fire clay mined is used near the mine site for producing refractories. A general process diagram is given in Figure 39.

There is no water used in fire clay mining. However, due to rainfall and ground water seepage, there can be water which accumulates in the pits and must be removed. Mine pumpout is intermittent depending on the frequency of rainfall and the geographic location. Flow rates are not generally available. In many cases the facilities provide protective earthen dams and ditches to prevent intrusion of external storm runoff into the clay pits. No process water is used. The solid waste generated in fire clay mining is overburden which is used as fill to eventually reclaim mined-out areas.

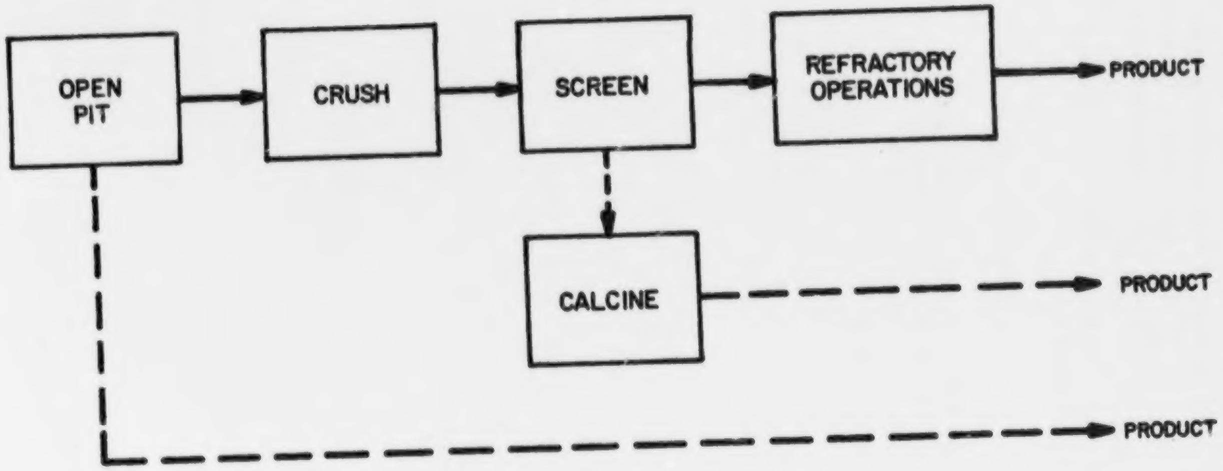

OPEN PIT
CRUSH
SCREEN
REFRACTORY OPERATIONS
PRODUCT
CALCINE
PRODUCT
PRODUCT

FIGURE 39
FIRE CLAY MINING AND PROCESSING

FULLER'S EARTH (SIC 1454)

Fuller's Earth is a clay, usually high in magnesia, which has decolorizing and absorptive properties. Production from the region that includes Decatur County, Georgia, and Gadsden County, Florida, is composed predominantly of the distinct clay mineral attapulgite. Most of the Fuller's Earth occurring in the other areas of the U.S. contains primarily montmorillonite.

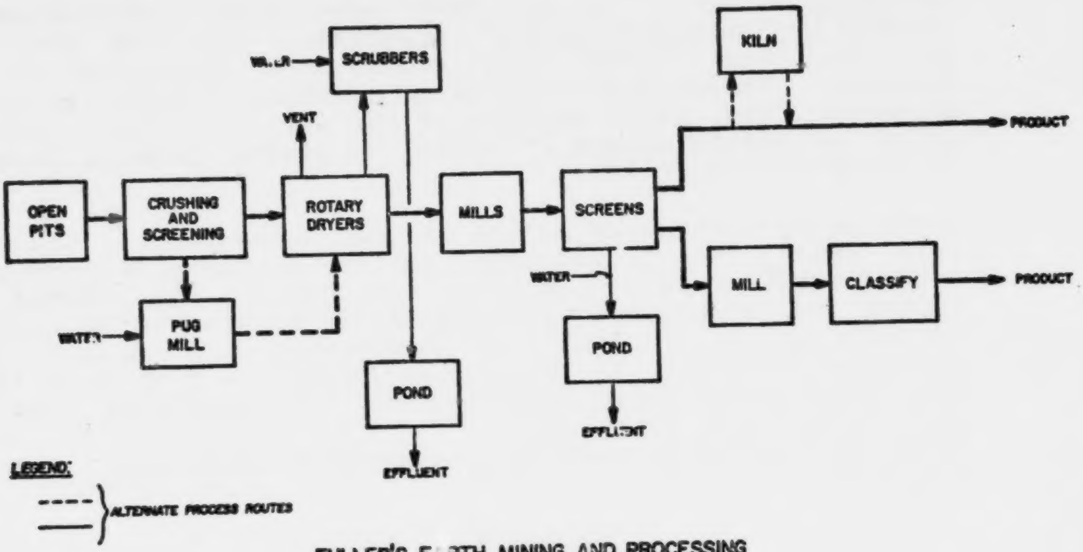
ATTAPULGITE

Attapulgite is mined from open pits, with removal of overburden using scrapers and draglines. The clay is also removed using scrapers and draglines and is trucked to the facility for processing. Processing consists of crushing and grinding, screening and air classification, pug milling (optional), and a heat treatment that may vary from simple evaporation of excess water to thermal alteration of crystal structure. A general process diagram is given in Figure 40.

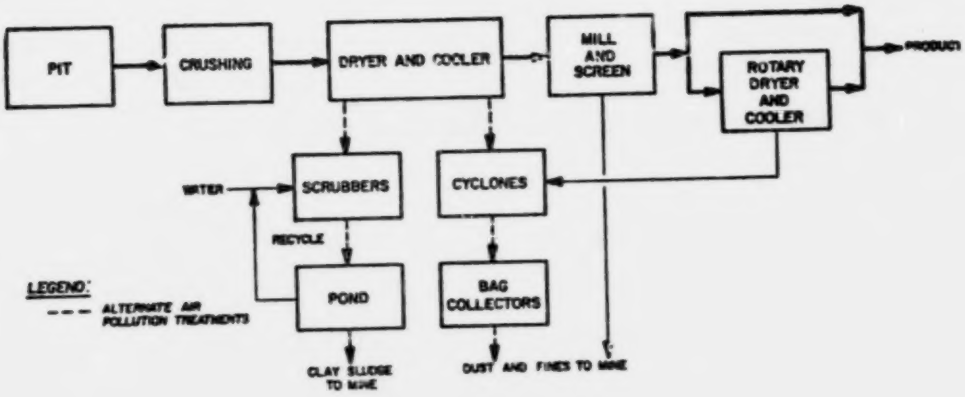
No water is used in the mining, but rain and ground water do collect in the pits, particularly during the rainy season. Untreated creek water serves as make-up for facilities 3058 and 3060. Water is used by facility 3058 for cooling, pug milling, and during periodic overload for waste fines slurrying. This slurrying has not occurred since installation of a fines reconstitution system. However it is maintained as a back-up system. Facility 3060 also uses water for cooling and pug milling, and, in addition, uses water in dust scrubbers for air pollution control. Typical flows are:

	l/kkg of product (gal/ton)	
	3058	3060
Intake:		
Make-up	460 (110)	unknown
Use:		
cooling	184 (44)	unknown
waste disposal and dust collection	230 (55)	345-515 (82-122)
pug mill	46 (11)	42 (10)
Discharge:		
cooling water	none	unknown
process discharge	none	none
evaporation	230 (55)	42 (10)

FIGURE 40


WATER
SCRUBBERS
KILN
VENT
PRODUCT
OPEN PITS
CRUSHING AND SCREENING
ROTARY DRYERS
MILLS
SCREENS
WATER
MILL
CLASSIFY
PRODUCT
WATER
PUG MILL
POND
POND
EFFLUENT
EFFLUENT
LEGEND:
ALTERNATE PROCESS ROUTES

FULLER'S EARTH MINING AND PROCESSING
(ATTAPULGITE)


PIT
CRUSHING
DRYER AND COOLER
MILL AND SCREEN
ROTARY DRYER AND COOLER
PRODUCT
WATER
SCRUBBERS
CYCLONES
RECYCLE
POND
BAG COLLECTORS
LEGEND:
ALTERNATE AIR POLLUTION TREATMENTS
CLAY SLUDGE TO MINE
DUST AND FINES TO MINE

FULLER'S EARTH MINING AND PROCESSING
(MONTMORILLONITE)

MONTMORILLONITE

Montmorillonite is mined from open pits. Overburden is removed by scrapers and/or draglines, and the clay is draglined and loaded onto trucks for transport to the facility. Processing consists of crushing, drying, milling, screening, and, for a portion of the clay, a final drying prior to packaging and shipping. A general process diagram is given in Figure 40.

There is no water used in the mining operations. However, rain water and ground water collect in the pits forming a murky colloidal suspension of the clay. This water is pumped to worked-out pits where it settles to the extent possible and is discharged intermittently to a nearby body of water, except in the case of facility 3073 which uses this water as scrubber water makeup. The estimated flow is up to 1140 l/day (300 gpd).
Water is used in processing only in dust scrubbers. Typical flows are:

	1/kkg product (gal/ton)			
Facility	3059	3072	3073	3323
Dust Scrubbers	1,930 (460)	500 (120)	143 (34)	3,650 (876)
Discharge	none	150 (36)	none	---

Solid waste generated in mining montmorillonite is overburden which is used as fill to reclaim worked-out pits. Waste is generated in processing as dust and fines from milling, screening, and drying operations. The dust and fines which are gathered in bag collectors from drying operations are hauled, along with milling and screening fines, back to the pits as fill. Slurry from scrubbers is sent to a settling pond with the muds being returned to worked-out pits after recycling the water.

KAOLIN (SIC 1455)

DRY PROCESS

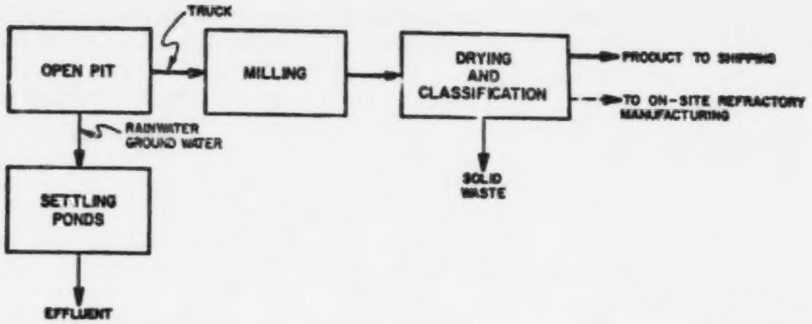
The clay is mined in open pits using shovels, caterpillars, carry-alls and pan scrapers. Trucks haul the kaolin to the facility for processing. At facilities 3035, 3062, 3063 the clay is crushed, screened, and used for processing into refractory products. Processing at facility 3036 consists of grinding, drying, classification and storage. A general dry process diagram is given in Figure 41. There is no water used in the mining or processing of kaolin at these four facilities. There is rainwater and ground water which accumulates in the pits and must be pumped out. There is no waste generated in the mining of the kaolin other than overburden, and in the processing, solid waste is generated from classification.

WET PROCESS

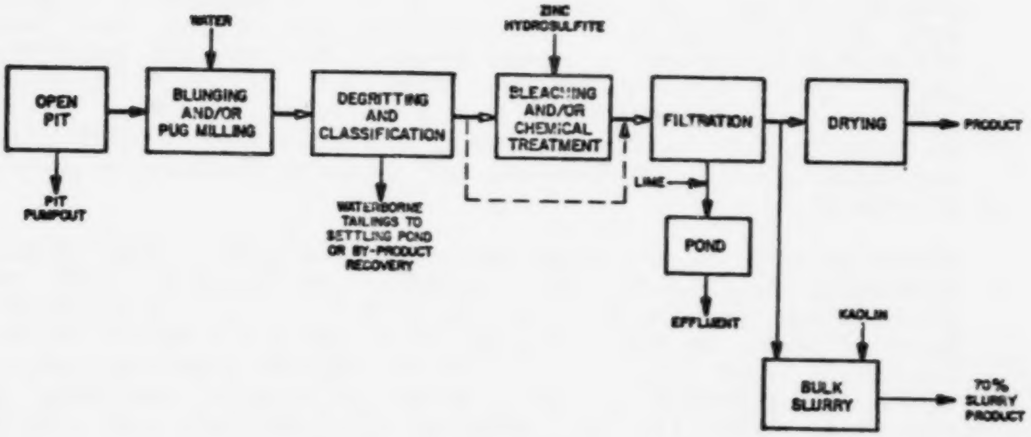
Sixty percent of the U.S. production of kaolin is by this general process. Mining of kaolin is an open pit operation using draglines or pan scrapers. The clay is then trucked to the facility or, in the case of facility 3025, some preliminary processing is performed near the mine site including blunging or pug milling, degritting, screening and slurrying prior to pumping the clay to the main processing facility. Subsequent operations are hydroseparation and classification, chemical treatment (principally bleaching with zinc hydrosulfite), filtration, and drying via tunnel dryer, rotary dryer or spray dryer. For special properties, other steps can be taken such as magnetic separation, delamination or attrition (facility 3024). Also, facility 3025 ships part of the kaolin product as slurry (70% solids) in tank cars. A general wet process diagram is given in Figure 41.

Water is used in wet processing of kaolin for pug milling, blunging, cooling, and slurrying. At facility 3024, water is obtained from deep wells, all of which is chlorinated and most of which is used as facility process water with no recycle. Facility 3025 has a company-owned ground water system as a source and also incoming slurry provides some water to the process none of which is recycled. Typical water flows are:

FIGURE 41


TRUCK
OPEN PIT
MILLING
DRYING AND CLASSIFICATION
PRODUCT TO SHIPPING
TO ON-SITE REFRACTORY MANUFACTURING
RAINWATER GROUND WATER
SOLID WASTE
SETTLING PONDS
EFFLUENT

DRY KAOLIN MINING AND PROCESSING
FOR GENERAL PURPOSE USE


WATER
ZINC HYDROSULFITE
OPEN PIT
BLUNGING AND/OR PUG MILLING
DEGRITTING AND CLASSIFICATION
BLEACHING AND/OR CHEMICAL TREATMENT
FILTRATION
DRYING
PRODUCT
PIT PUMPOUT
WATERBORNE TAILINGS TO SETTLING POND OR BY-PRODUCT RECOVERY
LIME
POND
EFFLUENT
KAOLIN
BULK SLURRY
70% SLURRY PRODUCT

WET KAOLIN MINING AND PROCESSING
FOR HIGH GRADE PRODUCT

	1/kkg product (gal/ton) 3024	 3025
water intake	4,250 (1,020)	4,290 (1030)
process waste water	3,400 (810)	4,000 (960)
water evaporated, etc.	850 (210)	290 (70)

These facilities do not recycle their process water but discharge it after treatment. Recycle of this water is claimed to interfere with the chemical treatment.

Waste is generated in kaolin mining as overburden which is stripped off to expose the kaolin deposit. In the processing, waste is generated as underflow from hydroseparators and centrifuges (facility 3024), and sand and muds from filtration and separation operations. Zinc originates from the bleaching operations. The raw waste loads at these two facilities are:

Waste Material	kg/kkg product (lb/1000 lb) 3024	 3025
zinc	0.37	0.5
dissolved solids	8	10
suspended solids	35	100

The dissolved solids are principally sulfates and sulfites and the suspended solids are ore fines and sand.

BALL CLAY (SIC 1455)

After overburden is removed, the clay is mined using front-end loaders and/or draglines. The clay is then loaded onto trucks for transfer to the processing facility. Processing consists of shredding, milling, air separation and bagging for shipping. Facilities 5684 and 5685 have additional processing steps including blunging, screening, and tank storage for sale of the clay in slurry form, and rotary drying directly from the stockpile for a dry unprocessed ball clay. A general process diagram is given in Figure 42.

There is no water used in ball clay mining. However, when rain and ground water collects in the mine there is an intermittent discharge. There is usually some diking around the mine to prevent run-off from flowing in. In ball clay processing, two of the facilities visited use a completely dry process. The others produce a slurry product using water for blunging and for wet scrubbers. Well water serves as the source for the facilities which use water in their processing. Typical flows are:

	l/kkg of product (gal/ton)		
	5684	5685	5689
Blunging	unknown	42 (10)	none
Scrubber	88 (21)	1,080 (260)	4,300 (1,030)

Water used in blunging operations is either consumed in the product and or evaporated. Scrubber water is impounded in settling ponds and eventually discharged. Facilities 5685 and 5689 use water scrubbers for both dust collection from the rotary driers and for in-facility dust collection. Facility 5684 has only the former.

Ball clay mining generates a large amount of overburden which is returned to worked-out pits for land reclamation. The processing of ball clay generates dust and fines from milling and air separation operations. These fines are gathered in baghouses and returned to the process as product. At the facilities where slurrying and rotary drying are done, there are additional process wastes generated. Blunging and screening the clay for slurry product generates lignite and sand solid wastes after dewatering. The drying operation uses wet scrubbers which result in a slurry of dust and water sent to a settling pond. There are no data available on the amount of wastes generated in producing the slurry or the dry product, but the waste materials are limited to fines of low solubility minerals.

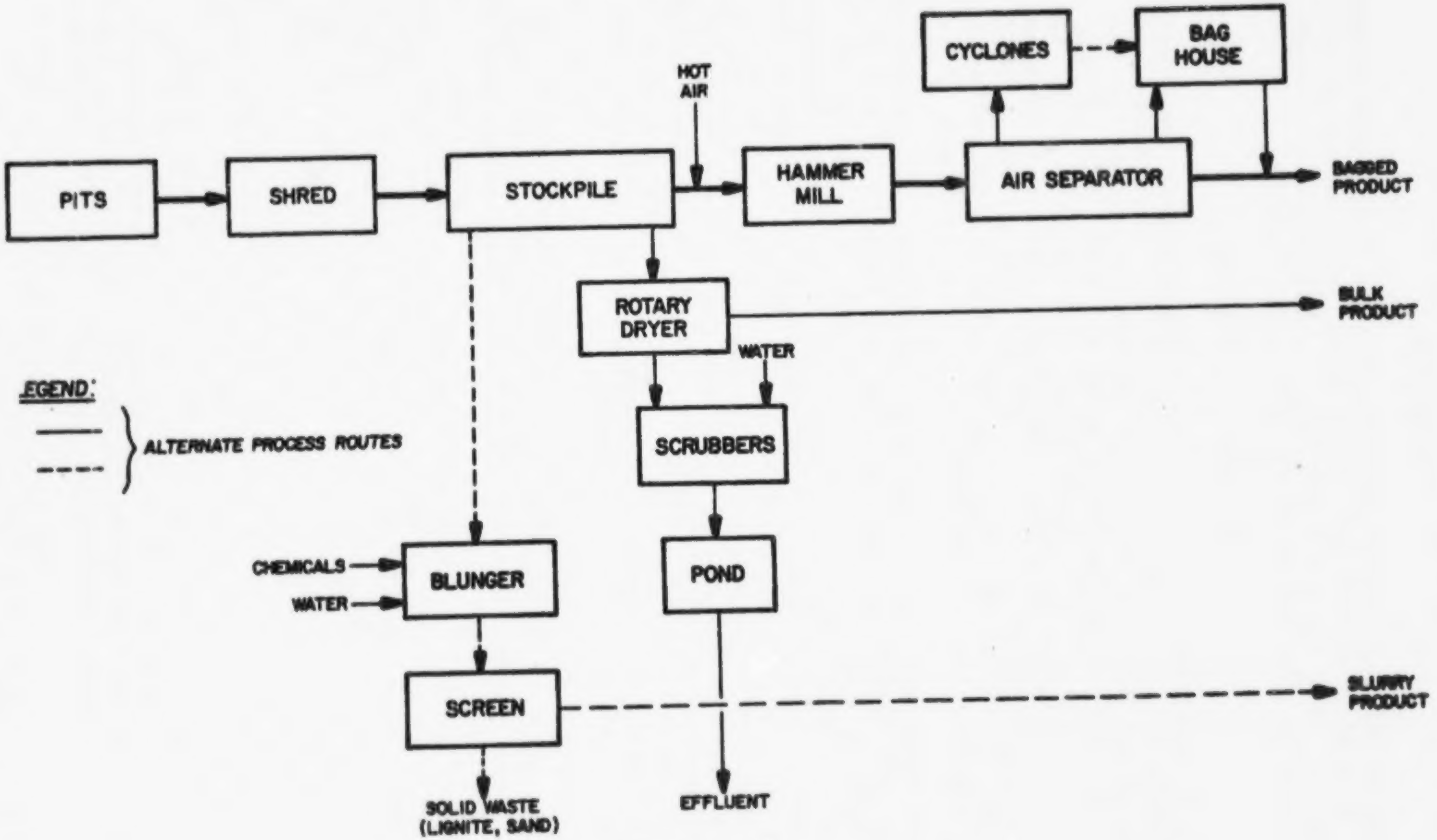

PITS
SHRED
STOCKPILE
HOT AIR
HAMMER MILL
AIR SEPARATOR
CYCLONES
BAG HOUSE
BAGGED PRODUCT
ROTARY DRYER
BULK PRODUCT
WATER
SCRUBBERS
POND
EFFLUENT
CHEMICALS
WATER
BLUNGER
SCREEN
SLURRY PRODUCT
SOLID WASTE (LIGNITE, SAND)
LEGEND:
ALTERNATE PROCESS ROUTES

FIGURE 47
BALL CLAY MINING AND PROCESSING

FELDSPAR

Feldspar mining and/or processing has been sub-categorized as follows: flotation processing and non-flotation (dry crushing and classification). Feldspathic sands are included in the Industrials Sands subcategory.

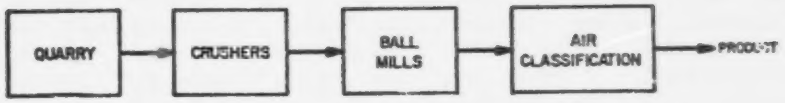
FELDSPAR - FLOTATION

This subcategory of feldspar mining and processing is characterized by dry operations at the mine and wet processing in the facility. About 73 percent of the total tonnage of feldspar sold or used in 1972 was produced by this process. Wet processing is carried out in five facilities owned by three companies. Data was obtained from all five of these facilities (3026, 3054, 3065, 3067, and 3068). A sixth facility is now coming into production and will replace one of the above five facilities in 1975.

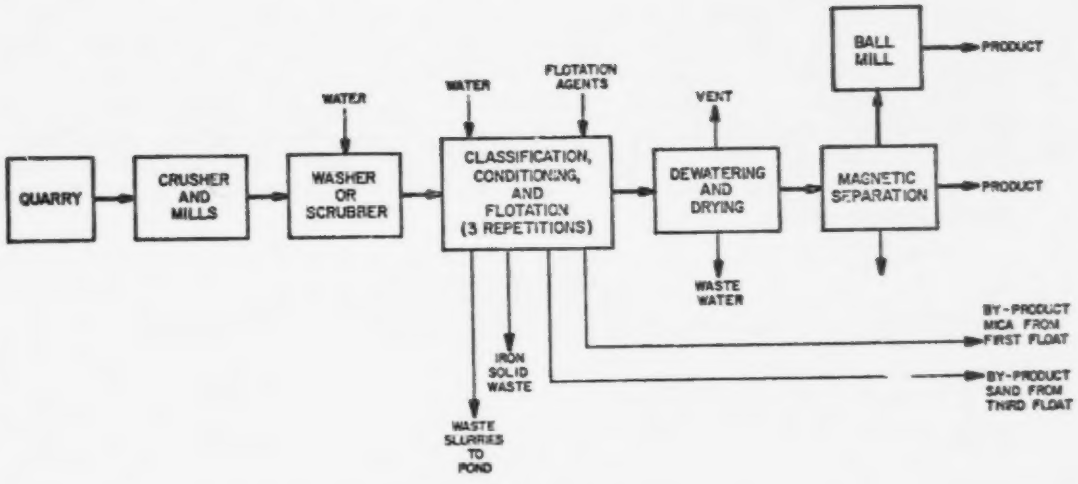
At all five facilities, mining techniques are quite similar: after overburden is removed, the ore is drilled and blasted, followed by loading of ore onto trucks by means of power shovels, draglines, or front end loaders for transport to the facility. In some cases, additional break-up of ore is accomplished at the mine by drop-balling. No water is used in mining at any location. The first step in processing the ore is crushing which is generally done at the facility, but sometimes at the mine (Facility 3068). Subsequent steps for all wet processing facilities vary in detail, but the basic flow sheet, as given in Figure 43, contains all the fundamentals of these facilities.

By-products from flotation include mica, which may be further processed for sale (Facilities 3054, 3065, 3067, and 3068), and quartz or sand (Facilities 3026, 3054, and 3068). At Facilities 3065 and 3067, a portion of the total flow to the third flotation step is diverted to dewatering, drying, guiding, etc., and is sold as a feldspathic sand. Water is not used in the quarrying of feldspar. There is occasional drainage from the mine, but pumpout is not generally practiced. Wet processing of feldspar does result in the use of quite significant amounts of water. At the facilities visited, water was obtained from a nearby lake, creek, or river and used without any pre-treatment. Recycle of water is minimal, varying from zero at several facilities to a maximum of about 17 percent at Facility 3026. The primary reason for little or no water recycle is the possible build-up of undesirable soluble organics and fluoride ion in the flotation steps. However, some water is recycled in some facilities to the initial washing and

FIGURE 43


QUARRY
CRUSHERS
BALL MILLS
AIR CLASSIFICATION
PRODUCT

FELDSPAR MINING AND PROCESSING
(DRY)


QUARRY
CRUSHER AND MILLS
WATER
WASHER OR SCRUBBER
WATER
FLOTATION AGENTS
CLASSIFICATION, CONDITIONING, AND FLOTATION (3 REPETITIONS)
VENT
DEWATERING AND DRYING
WASTE WATER
BALL MILL
PRODUCT
MAGNETIC SEPARATION
PRODUCT
BY-PRODUCT MICA FROM FIRST FLOAT
BY-PRODUCT SAND FROM THIRD FLOAT
IRON SOLID WASTE
WASTE SLURRIES TO POND

FELDSPAR MINING AND PROCESSING
(WET)

crushing steps, and some recycle of water in the fluoride flotation step is practiced at facility 3026.

Total water use at these facilities varies from 7,000 to 22,200 l/kkg of ore processed (1,680 to 5,300 gal/ton). Most of the process water used in these facilities is discharged. Some water is lost in tailings and drying. This is of the order of 1 percent of the water use at facility 3065. The use of the process water in the flotation steps amounts to at least one-half of the total water use. The water used in the fluoride reagent flotation step ranges from 10 to 25 percent of the total flow depending on local practice and sand-to-feldspar ratio. Only two of these five facilities use any significant recycling of water. These are:

facility 3026 - 17 percent of intake (on the average)

facility 3067 - 10 percent of intake

Mining operations at the open pits result in overburden of varying depth. The overburden is used for land reclamation of nearby worked-out mining areas. Waste recovery and handling at the processing facilities is a major consideration, as large tonnages are involved. Waste varies from a low of 26 percent of mined ore at Facility 3065 to a high of 53 percent at Facility 3067. The latter value is considerably larger due to the fact that this facility does not sell the sand from its feldspar flotation. Most of the other facilities are able to sell all or part of their by-product sand. Typical flotation reagants used in this production subcategory contain hydrofluoric acid, sulfuric acid, sulfonic acid, frothers, amines and oils. The raw waste data calculated from information supplied by these facilities are:

	kg/kkg of ore processed (lb/1000 lb)	
facility	ore tailings and slimes	fluoride
3026	270	0.22
3054	410	0.24
3065	260	0.20
3067	530	est. 0.25
3068	350	est. 0.25

FELDSPAR - NON-FLOTATION

This subcategory of feldspar mining and processing is characterized by completely dry operations at both the mine and the facility. Only two such facilities were found to exist in the U.S. and both were visited. Together they represent approximately 8.5 percent of total U.S. feldspar production. However, there are two important elements of difference between these two operations. All of facility 3032 production of feldspar is sold for use as an abrasive in scouring powder. At facility 3064, the high quality orthoclase (potassium aluminum silicate) is primarily sold to manufacturers of electrical porcelains and ceramics.

Underground mining is done at Facility 3032 on an intermittent, as-needed, basis using drilling and blasting techniques. A very small amount of water is used for dust control during drilling. At Facility 3064, the techniques are similar, except that mining is in an open pit and is carried on for 2-3 shifts/day and 5-6 days/week depending on product demand. Hand picking is accomplished prior to truck transport of ore to the facility.

At the two facilities the ore processing operations are virtually identical. They consist of crushing, ball milling, air classification, and storage prior to shipping. Product grading is performed by air classification. A schematic flow sheet is shown in Figure 43.

At the mine 3032, water is used to suppress dust while drilling. It is spilled on the ground and is readily absorbed; volume is only about 230 l/day (about 60 gpd). No water is used for processing at the mine. At Facility 3064, no water is used at the mine. Water is used at a daily rate of <1,900 l/day (500 gpd) to suppress dust in the crushers. No pre-treatment is applied to water used at either facility.

At Facility 3032, there are no mine wastes generated, and only a small quantity of high-silica solid wastes result from the facility, and the material is used as land fill. At Facility 3064, the rejects from hand picking are used as mine fill. There is very little waste at the facility.

KYANITE

Kyanite is produced in the U.S. from 3 open pit mines, two in Virginia and one in Georgia. In this study two of these three mines were visited, one in Virginia, and one in Georgia, representing approximately 75 percent of the U.S. production of kyanite.

Kyanite is mined in dry open quarries, using blasting to free the ore. Power shovels are used to load the ore onto trucks which then haul the ore to the processing facility. Processing consists of crushing and milling, classification and desliming, flotation to remove impurities, drying, and magnetic separation. Part of the kyanite is converted to mullite via high temperature firing at 1540°-1650°C (2800-3000°F) in a rotary kiln. A general process diagram is given in Figure 44.

Water is used in kyanite processing in flotation, classification, and slurry transport of ore solids. This process water amounts to:

	l/kkg of kyanite (gal/ton)
facility 3015	29,200 (7,000)
facility 3028	87,600 (21,000)

The process water is recycled, and any losses due to evaporation and pond seepage are replaced with make-up water. Make-up water for facility 3028 is used at a rate of 4,200,000 l/day (0.288 mgd) and facility 3015 obtains make-up water from run-off draining into the settling pond and also from an artesian well.

Wastes are generated in the processing of the kyanite, in classification, flotation and magnetic separation operations. These wastes consist of pyrite tailings, quartz tailings, flotation reagents, muds, sand and iron scalpings. These wastes are greater than 50 percent of the total mined material.

waste material	kg/kkg of kyanite (lb/1000 lb)
facility 3015 tailings	2,500
facility 3028 tailings	5,700

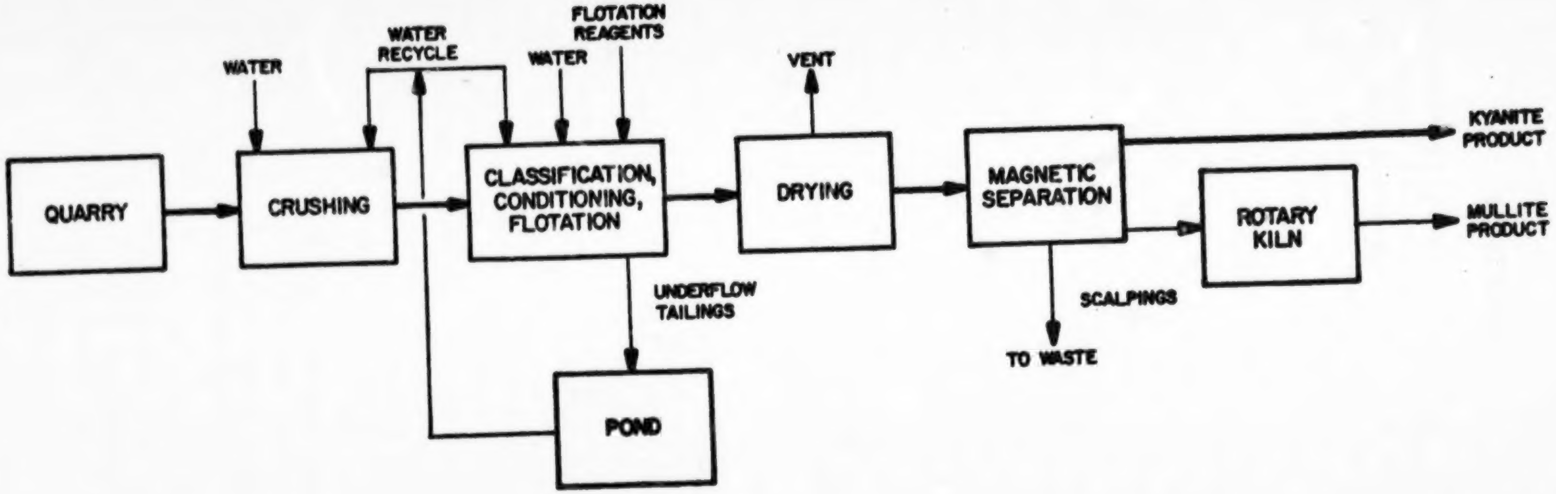

QUARRY
WATER
CRUSHING
WATER RECYCLE
WATER
FLOTATION REAGENTS
CLASSIFICATION, CONDITIONING, FLOTATION
UNDERFLOW TAILINGS
POND
VENT
DRYING
MAGNETIC SEPARATION
TO WASTE
SCALPINGS
ROTARY KILN
KYANITE PRODUCT
MULLITE PRODUCT

FIGURE 44
KYANITE MINING AND PROCESSING

MAGNESITE

There is only one known U.S. facility that produces magnesia from naturally occurring magnesite ore. This facility, facility 2063, mines and beneficiates magnesite ore from which caustic and dead burned magnesia are produced. The present facility consists of open pit mines, heavy media separation (HMS) and a flotation facility.

All mining operations are accomplished by the open pit method. The deposit is chemically variable, due to the interlaid horizons of dolomite and magnesite, and megascopic identification of the ore is difficult. The company has devised a selective quality control system to obtain the various grades of ore required by the processing facilities. The pit is designed with walls inclined at 60°, with 6 m (20 ft) catch benches every 15 m (50 ft) of vertical height. The crude ore is loaded by front end loaders and shovels and then trucked to the primary crusher. The quarry is located favorably so that there is about 2 km (1.25 mi) distance to the primary crusher. About 2260 kkg/day (2500 tons/day) of ore are crushed in the mill for direct firing and beneficiation. There is about 5 percent waste at the initial crushing operation which results from a benefication step. The remainder of the crusher product is further processed thru crushing, sizing and beneficiating operations.

The flow of material through the facility, for direct firing, follows two major circuits: (1) the dead burned magnesite circuit, and (2) the light burned magnesite circuit. In the dead burned magnesite circuit, the ore is crushed to minus 1.9 cm (3/4 in) in a cone crusher. The raw materials are dry ground in two ball mills that are in closed circuit with an air classifier. The minus 65 mesh product from the classifier is transported by air slides to the blending silos. From the silos the dry material is fed to pug mills where water and binding materials are added. From the pug mills the material is briquetted, dried, and stored in feed tanks ahead of rotary kilns. The oil or natural gas fired kilns convert the magnesite into dense magnesium clinker of various chemical constituents, depending upon the characteristics desired in the product. After leaving the kiln, the clinker is cooled by an air quenched rotary or grate type coolers, crushed to desired sizes, and stored in large storage silos for shipment.

In the light burned magnesite circuit, minus 1.9 cm (3/4 in) magnesite is fed to two Herreshoff furnaces. By controlling the amount of CO_2 liberated from the magnesite a caustic oxide is produced from these furnaces. The magnesium oxide is cooled and ground in a ball mill into a variety of grades and sizes, and is either bagged or shipped in bulk.

Magnesite is beneficiated at facility 2063 by either heavy media separation (HMS) and/or froth flotation methods. In the HMS facility, the feed is crushed to the proper size, screened, washed and drained on a vibratory screen to eliminate the fines as much as possible. The screened feed is fed to the separating cone which contains a suspension of finely ground ferro-silicon and/or magnetite in water, maintained at a predetermined specific gravity. The light fraction floats and is continuously removed by overflowing a weir. The heavy particles sink and are continuously removed by an airlift.

The float weir overflow and sink airlift discharge go to a drainage screen where 90 percent of the medium carried with the float and sink drains through the screen and is returned to the separatory cone. The "float" product passes from the drainage section of the screen to the washing section where the fines are completely removed by water sprays. The solid wastes from the wet screening operations contain -0.95 to +3.8 cm (-3/8 to +1-1/2in) material which is primarily used for the construction of settling pond contour. The fines from the spray screen operations, along with the "sink" from the separating cone, are sent into the product thickener. In the flotation facility, the feed is crushed, milled, and classified and then sent into the cyclone clarifier. Make-up water, along with the process recycled water, is introduced into the cyclone classifier. The oversize from the classifier is ground in a ball mill and recycled back to the cyclone. The cyclone product is distributed to the rougher flotation process and the floated product is then routed to cleaner cells which operate in series. The flotation concentrate is then sent into the product thickener. The underflow from this thickener is filtered, dried, calcined, burned, crushed, screened and bagged for shipment.

The tailings from the flotation operation and the filtrate constitute the waste streams of these facilities and are sent into the tailings thickener for water recovery. The overflows from either thickener are recycled back to process. The underflow from the tailings thickener containing about 40 percent solids is impounded in the facility. A simplified flow diagram for this facility is given in Figure 45.

This facility's fresh water system is serviced by eight wells. All wells except one are hot water wells, 50 to 70°C (121° to 160°F). The total mill intake water is 2,200,000

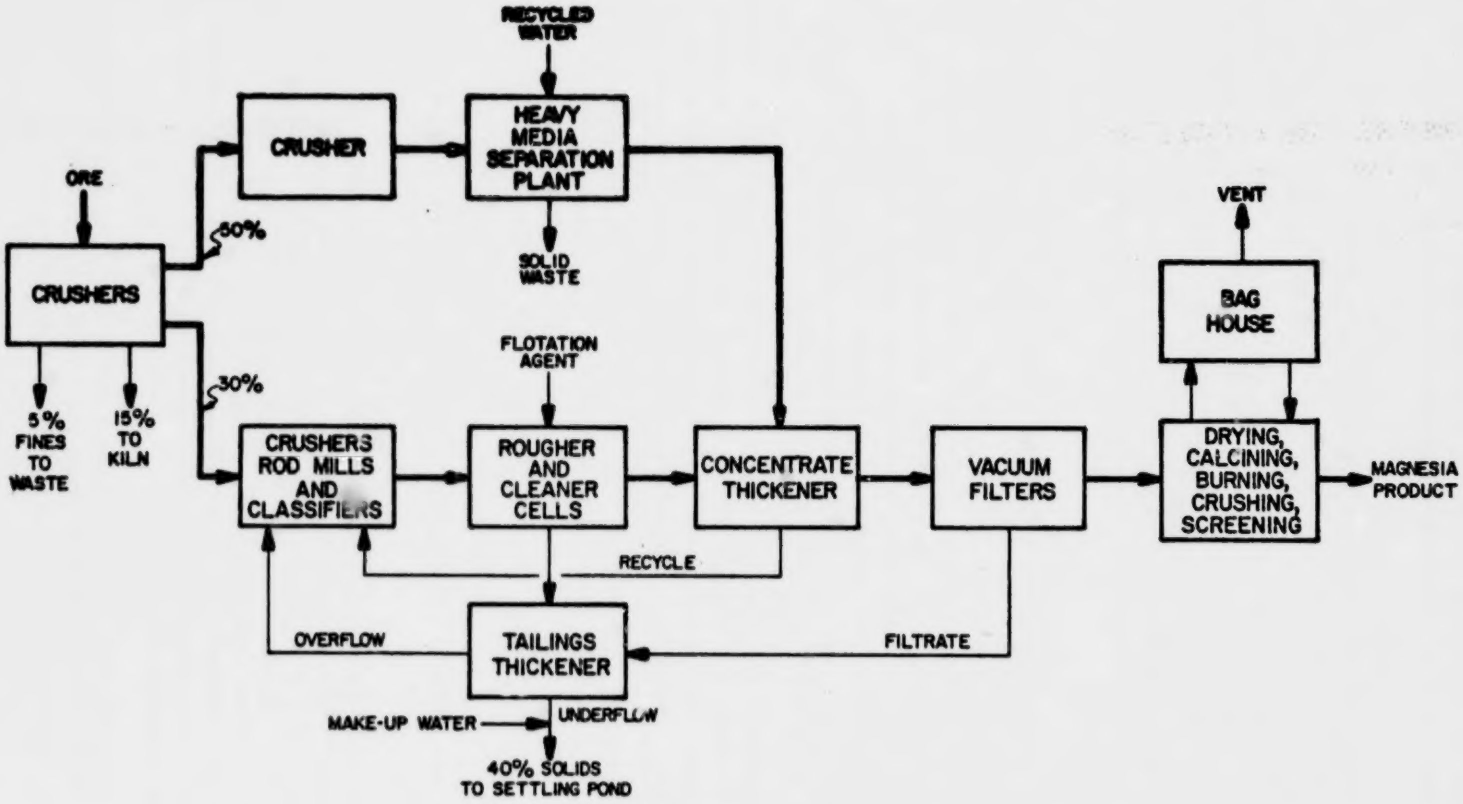

RECYCLED WATER
ORE
CRUSHERS
50%
30%
5% FINES TO WASTE
15% TO KILN
CRUSHER
HEAVY MEDIA SEPARATION PLANT
SOLID WASTE
FLOTATION AGENT
CRUSHERS ROD MILLS AND CLASSIFIERS
ROUGHER AND CLEANER CELLS
CONCENTRATE THICKENER
VACUUM FILTERS
VENT
BAG HOUSE
DRYING, CALCINING, BURNING, CRUSHING, SCREENING
MAGNESIA PRODUCT
RECYCLE
OVERFLOW
TAILINGS THICKENER
FILTRATE
MAKE-UP WATER
UNDERFLOW
40% SOLIDS TO SETTLING POND

FIGURE 45
MAGNESITE MINING AND PROCESSING

l/day (580,000 gal/day), 88 percent of which is cooled prior to usage. The hydraulic load of this facility is given below:

water consumption	l/day (gal/day)
process water to refine the product	163,000 (43,000)
road dust control	227,000 (60,000)
sanitary	11,360 (3,000)
tailing pond evaporation	492,000 (130,000)
tailing pond percolation	757,000 (200,000)
evaporation in water sprays, Baker coolers & cooling towers	545,000 (144,000)

The raw waste from this facility consists of the underflow from the tailings thickeners and it includes about 40 percent suspended solids amounting to 590,000 kg/day (1,300,000 lb/day).

SHALE AND COMMON CLAY

Shale is a consolidated sedimentary rock composed chiefly of clay minerals, occurring in varying degrees of hardness. Shales and common clays are for the most part used by the producer in fabricating or manufacturing structural clay products (SIC 3200) so only the mining and processing is discussed here. Less than 10 percent of total clay and shale output is sold outright. Therefore, for practical purposes, nearly all such mining is captive to ceramic or refractory manufactures. Shale and common clay are mined in open pits using rippers, scrapers, bulldozers, and front-end loaders. Blasting is needed to loosen very hard shale deposits. The ore is then loaded on trucks or rail cars for transport to the facility. There, primary crushing, grinding, screening, and other operations are used in the manufacture of many different structural clay products. A general process diagram is given in Figure 46. Solid waste is generated in mining as overburden which is used as fill to reclaim mined-out pits. Since ceramic processing is not covered, no processing waste is accounted for.

There is no water used in shale or common clay mining, however, due to rainfall and ground water seepage, there can be water which accumulates in the mines and must be removed. Mine pumpout is intermittent depending on rainfall frequency and geographic location. In many cases, facilities will build small earthen dams or ditches around the pit to prevent inflow of rainwater. Also shale is, in most cases, so hard that run off water will not pickup significant suspended solids. Flow rates are not generally available for mine pumpout.

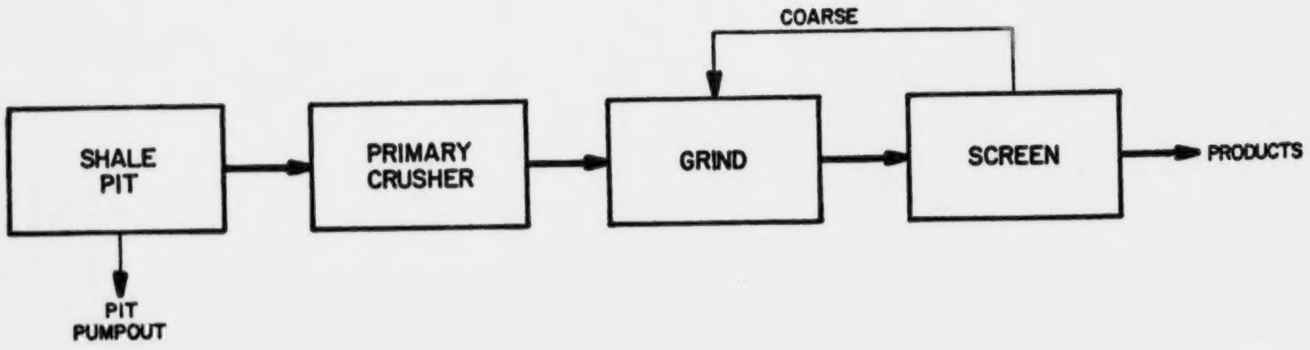

COARSE
SHALE PIT
PRIMARY CRUSHER
GRIND
SCREEN
PRODUCTS
PIT PUMPOUT

FIGURE 46
SHALE MINING AND PROCESSING

APLITE

Aplite is found in quantity in the U.S. only in Virginia and is mined and processed by only two facilities, both of which are discussed below. The deposit mined by facility 3016 is relatively soft and the ore can be removed with bulldozers, scrapers, and graders, while that mined by facility 3020 requires blasting to loosen from the quarry. The ore is then loaded on trucks and hauled to the processing facility.

Facility 3016 employs wet crushing and grinding, screening, removal of mica and heavy minerals via a series of wet classifiers, dewatering and drying, magnetic separation and final storage prior to shipping. Water is used at facility 3016 for crushing, screening and classifying at a rate of 38,000,000 l/day (10,000,000 gpd) which is essentially 100% recycled. Dust control requires about 1,890,000 l/day (500,000 gpd) of water which is also recycled. Any make-up water needed due to evaporation losses comes from the river. There is no mine pumpout at facility 3016 and any surface water which accumulates drains naturally to a nearby river.

Facility 3020 processing is dry, consisting of crushing and drying, more crushing, screening, magnetic separation and storage for shipping. However, water is used for wet scrubbing to control air pollution. A process flow diagram is given in Figure 47 depicting both processes. This water totals 1,230,000 l/day (324,000 gpd) with no recycle. There is occasional mine pumpout.

	l/kkg product (gal/ton)	
process use:	3016	3020
scrubber or dust control	3,600 (870)	5,900 (1,420)
crush, screen, classify	12,700 (3,040)	0
net discharge (less mine pumpout)	approx. 0	5,900 (1,420)
mine pumpout	0	not given
make-up water intake	not given	5,900 (1,420)

Mining waste is overburden and mine pumpout. The processing wastes are dusts and fines from air classification, iron bearing sands from magnetic separation, and tailings and heavy minerals from wet classification operations. The latter wastes obviously do not occur at the dry facility.

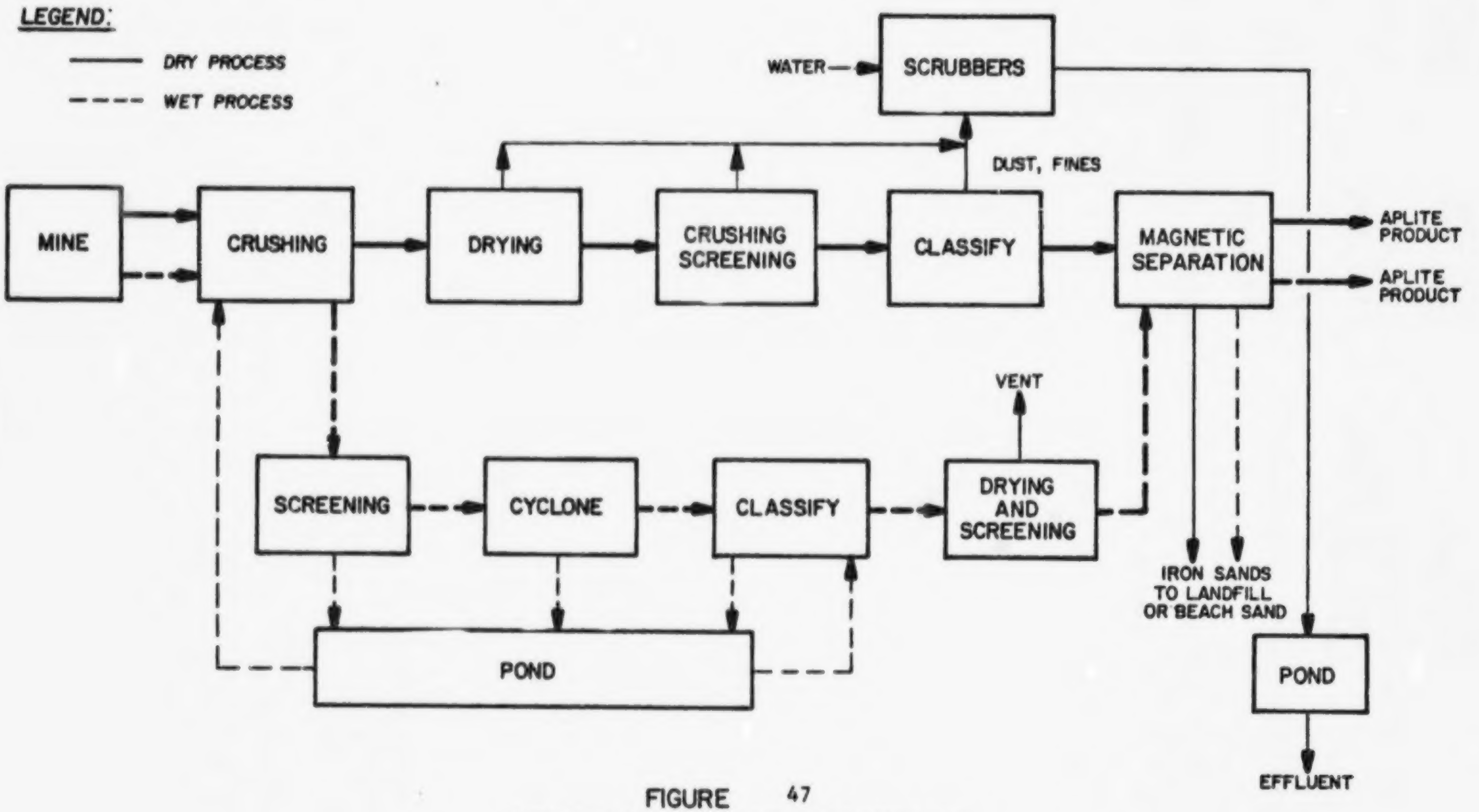

LEGEND:
DRY PROCESS
WET PROCESS
WATER
SCRUBBERS
DUST, FINES
MINE
CRUSHING
DRYING
CRUSHING SCREENING
CLASSIFY
MAGNETIC SEPARATION
APLITE PRODUCT
APLITE PRODUCT
VENT
SCREENING
CYCLONE
CLASSIFY
DRYING AND SCREENING
IRON SANDS TO LANDFILL OR BEACH SAND
POND
POND
EFFLUENT

FIGURE 47
APLITE MINING AND PROCESSING

	Waste Materials	kkg/year (ton/yr)	kg/kkg product (lb/1000 lb)
facility 3016 (wet)	tailings and heavy minerals and fines	136,000 (150,000)	1,000
facility 3020 (dry)	dust and fines	9,600 (10,600)	175

Other solid wastes come from the magnetic separation step at facility 3020.

TALC, STEATITE, SOAPSTONE AND PYROPHYLLITE

There are 33 known facilities in the U.S. producing talc, steatite, soapstone and pyrophyllite. Twenty-seven of these facilities use dry grinding operations, producing ground products. Two utilize log washing and wet screening operations producing either crude talc or ground talc. Four are wet crude ore beneficiation facilities, three using froth flotation and one heavy media separation techniques.

DRY GRINDING

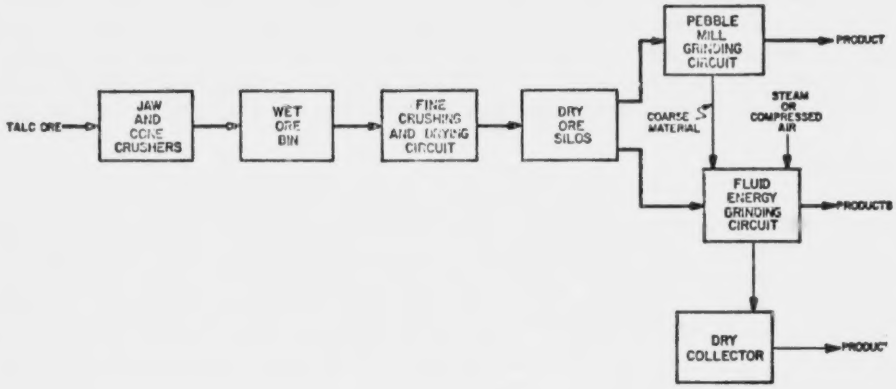
In a dry grinding mill, the ore is batched in ore bins and held until a representative ore sample is analyzed by the laboratory. Each batch is then assigned to a separate ore silo, and subsequently dried and crushed. The ore, containing less than 12% moisture is sent to fine dry grinding circuits in the mill. In the pebble mill (Hardinge circuit), which includes mechanical air separators in closed circuit, the ore is ground to minus 200 mesh rock powder. Part of the grades produced by this circuit are used principally by the ceramic industry; the remainder is used as feed to other grinding or classifying circuits. In a few facilities, some of this powder is introduced into the fluid energy mill to manufacture a series of minus 325 mesh products for the paint industry. Following grinding operations, the finished grades are pumped, in dry state, to product bulk storage silos. The product is either pumped to bulk hopper cars or to the bagging facility where it is packed in bags for shipment. A generalized process diagram for a dry grinding mill is given in Figure 48.

There is no water used in dry grinding facilities. Bag housed collectors are used throughout this industry for dust control. The fluid energy mills use steam. The steam generated in boilers is used in process and vented to atmosphere after being passed through a baghouse dust collector. The waste streams emanating from the boiler operations originate from conventional hot or cold lime softening process and/or zeolite softening operations, filter backwash, and boiler blowdown wastes. Even though these facilities do not use water in their process, some of them do have mine water discharge from their underground mine workings.

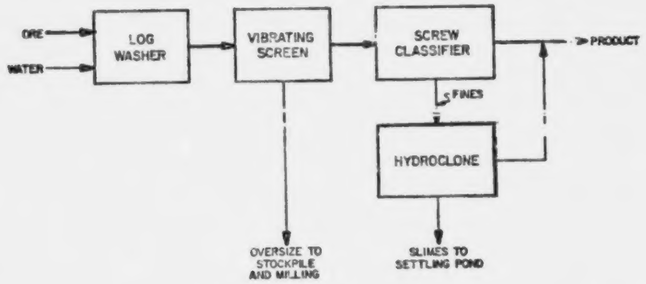
LOG WASHING AND WET SCREENING

At log washing facility 2034 and wet screening facility 2035, water is used to wash fines from the crushed ore. In both facilities, the washed product is next screened, sorted and classified. The product from the

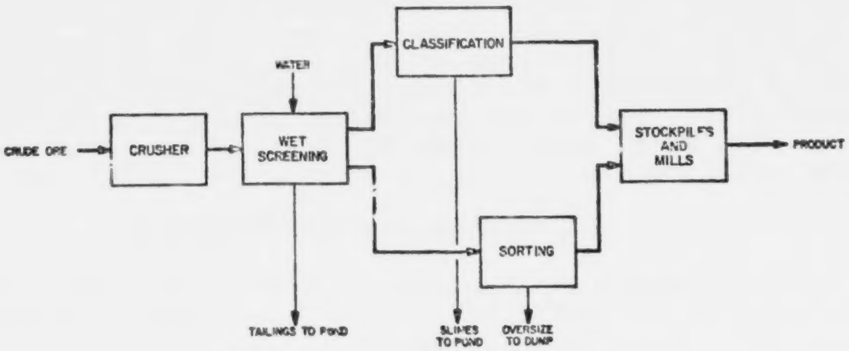
FIGURE 48


TALC ORE
JAW AND CONE CRUSHERS
WET ORE BIN
FINE CRUSHING AND DRYING CIRCUIT
DRY ORE SILOS
PEBBLE MILL GRINDING CIRCUIT
PRODUCT
COARSE MATERIAL
STEAM OR COMPRESSED AIR
FLUID ENERGY GRINDING CIRCUIT
PRODUCTS
DRY COLLECTOR
PRODUCT

TALC, STEATITE, SOAPSTONE AND PYROPHYLLITE MINING AND PROCESSING
(DRY)


ORE
WATER
LOG WASHER
VIBRATING SCREEN
SCREW CLASSIFIER
PRODUCT
FINES
HYDROCLONE
OVERSIZE TO STOCKPILE AND MILLING
SLIMES TO SETTLING POND

TALC, STEATITE, SOAPSTONE AND PYROPHYLLITE MINING AND PROCESSING
(LOG WASHING PROCESS)


CRUDE ORE
CRUSHER
WATER
WET SCREENING
CLASSIFICATION
SORTING
STOCKPILES AND MILLS
PRODUCT
TAILINGS TO POND
SLIMES TO POND
OVERSIZE TO DUMP

TALC, STEATITE, SOAPSTONE AND PYROPHYLLITE MINING AND PROCESSING
(WET SCREENING PROCESS)

classifier is either shipped as is or it is further processed in a dry grinding mill to various grades of finished product.

At facility 2034 wash water is sent into a hydroclone system for product recovery. The slimes from the hydroclone are then discharged into a settling pond for evaporation and drying. At facility 2035, the wash water, which carries the fines, is sent directly into a settling pond.

The wet facilities in this subcategory are operational on a six-month per year basis. During freezing weather, these facilities are shut down. Stockpiles of the wet facility products are accumulated in summer and used as source of feed in the dry grinding facility in winter. Simplified diagrams for facilities 2034 and 2035 are given in Figure 48.

Both facilities are supplied by water wells on their property. Essentially all water used is process water. Facility 2034 has a water intake of 182,000 l/day (48,000 gal/day) and facility 2035 has a water intake of 363,000 l/day (96,000 gal/day).

The raw waste from facility 2034 consists of the slimes from the hydroclone operation; that of facility 2035 is the tailings emanating from the wet screening operation and the slimes from the classifiers.

FLOTATION AND HEAVY MEDIA SEPARATION

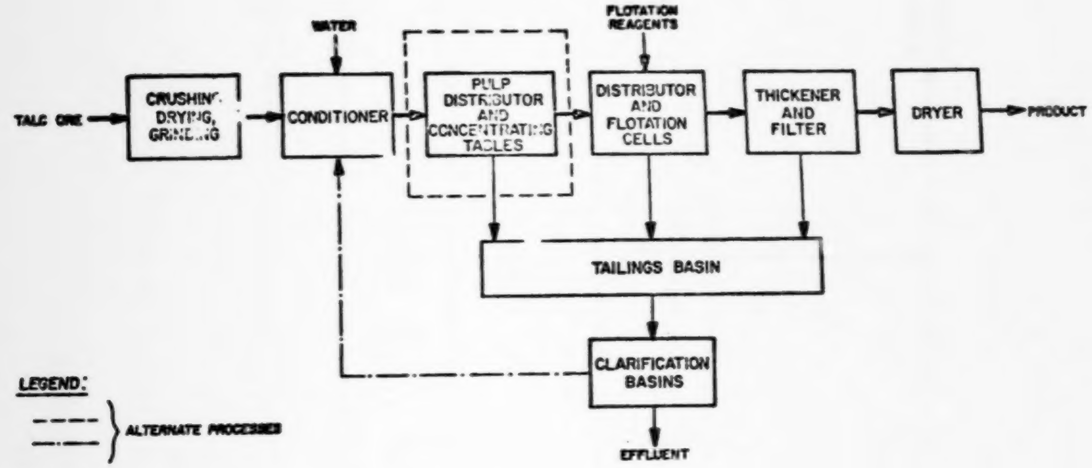
All four facilities in this subcategory use either flotation or heavy media separation techniques for upgrading the product. In two of the facilities (2031 and 2032) the ore is crushed, screened, classified and milled and then taken by a bucket elevator to a storage bin in the flotation section. From there it is fed to a conditioner along with well and recycled water. The conditioner feeds special processing equipment, which then sends the slurry to a pulp distributor. In facility 2031, the distributor splits the conditioner discharge over three concentrating tables from which the concentrates, the gangue material, are sent to the tailings pond. The talc middlings from the tables are then pumped to the flotation machines. However, in facility 2032, the distributor discharges directly into rougher flotation machines. A reagent is added directly into the cells and the floated product next goes to cleaning cells. The final float concentrate feeds a rake thickener which raises the solids content of the flotation product from 10 to 35 percent. The product from the thickener is next filtered on a rotary vacuum filter, and water from the filter flows back into the thickener. The filter cake is then dried and the finished product is sent into storage bins. The flotation tailings, along with thickener overflow, are sent to the tailings pond. A simplified flow diagram is given in Figure 49.

The flotation mill at facility 2031 consumes water, on the average, 25,400 l/kkg (6,070 gal/ton) of product. This includes 200 l/kkg product of non-contact cooling water (48 gal/ton) which is used in cooling the bearings of their crushers. Facility 2032 consumes 17,200 l/kkg (4150 gal/ton) product; 40 percent of which may be recycled back to process, after clarification. Recycled water is used in conditioners and as coolant in compressor circuits and for several other miscellaneous needs.

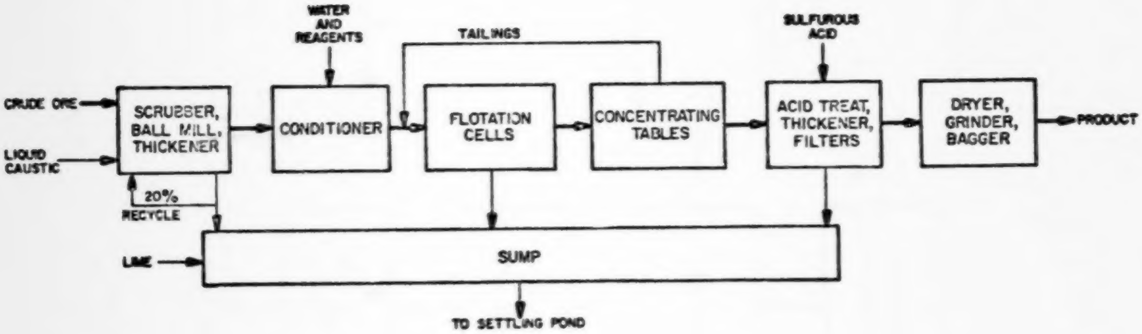
Facility 2033 processes ores which contain mostly clay, and it employs somewhat different processing steps. In this facility, the ore is scrubbed with the addition of liquid caustic to raise the pH, so as to suspend the red clay. The scrubbed ore is next milled and sent through thickening, flotation and tabling. The product from the concentrating tables is acid treated to dissolve iron oxides and other possible impurities. Acid treated material is next passed through the product thickener, the underflow from which contains the finished product. The thickener underflow is filtered, dried, ground and bagged. The waste streams consist of the flotation tailings, the overflow from the primary thickener and the filtrate. A generalized flow diagram is given in Figure 49. Facility 2033 consumes 16,800 l/kkg (4000 gal/ton) product; 20 percent of which is recycled back to process from the primary thickener operation. Facility 2044 consumes on the average l/kkg (1,305 gal/ton) total product.

Facility 2044 uses heavy media separation (HMS) technique for the beneficiation of a portion of their product. At this facility, the ore is crushed in a jaw crusher and sorted. The minus 2 inch material is dried before further crushing and screening operations; the plus 5.1 cm (2 in) fraction is crushed, screened and sized. The minus 3 to plus 20 mesh material resulting from the final screening operation is sent to the HMS unit for the rejection of high silica grains. The minus 20 mesh fraction is next separated into two sizes by air classification. Facility 2044 uses a wet scrubber on their #1 drier for dust control. On drier #2 (product drier) a baghouse is used and the dust recovered is marketed. A simplified process flow diagram for this facility is given in Figure 50. The hydraulic load of these facilities is summarized as follows:

FIGURE 49


TALC ORE
CRUSHING, DRYING, GRINDING
WATER
CONDITIONER
PULP DISTRIBUTOR AND CONCENTRATING TABLES
FLOTATION REAGENTS
DISTRIBUTOR AND FLOTATION CELLS
THICKENER AND FILTER
DRYER
PRODUCT
TAILINGS BASIN
CLARIFICATION BASINS
EFFLUENT
LEGEND:
ALTERNATE PROCESSES

TALC MINING AND PROCESSING
(FLOTATION PROCESS)


CRUDE ORE
LIQUID CAUSTIC
SCRUBBER, BALL MILL, THICKENER
20% RECYCLE
WATER AND REAGENTS
CONDITIONER
TAILINGS
FLOTATION CELLS
CONCENTRATING TABLES
SULFUROUS ACID
ACID TREAT, THICKENER, FILTERS
DRYER, GRINDER, BAGGER
PRODUCT
LIME
SUMP
TO SETTLING POND

TALC MINING AND PROCESSING
(IMPURE ORE)

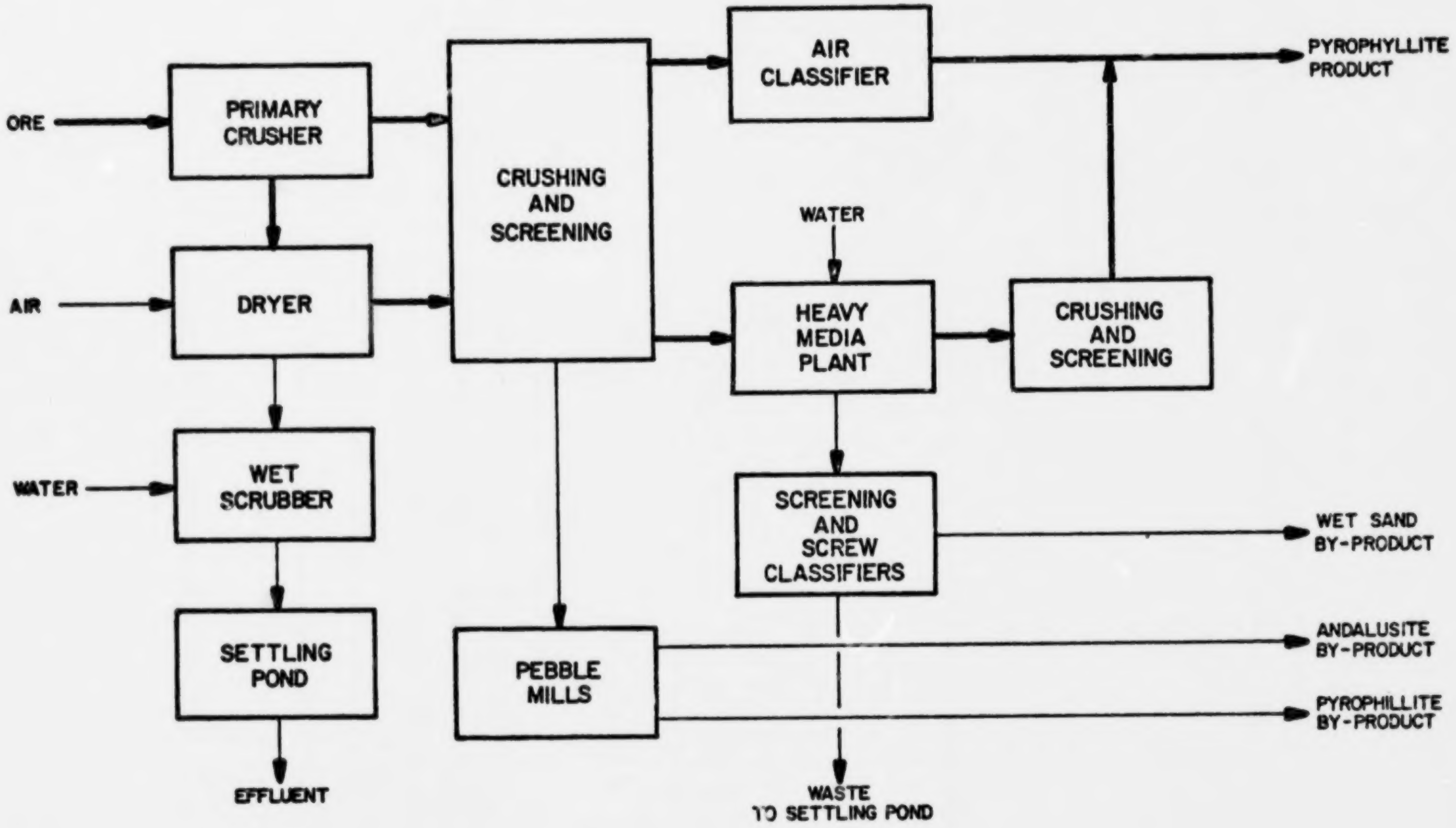

ORE
PRIMARY CRUSHER
AIR
DRYER
WATER
WET SCRUBBER
SETTLING POND
EFFLUENT
CRUSHING AND SCREENING
PEBBLE MILLS
AIR CLASSIFIER
WATER
HEAVY MEDIA PLANT
SCREENING AND SCREW CLASSIFIERS
WASTE TO SETTLING POND
CRUSHING AND SCREENING
PYROPHYLLITE PRODUCT
WET SAND BY-PRODUCT
ANDALUSITE BY-PRODUCT
PYROPHILLITE BY-PRODUCT

FIGURE 50
PYROPHYLLITE MINING AND PROCESSING
(HEAVY MEDIA SEPARATION)

Consumption at Facility No.	2031	2032	2033	2044
		l/day (gal/day)		
Process consumed	730,000 (192,000)	2,200,000 (583,000)	757,000 (200,000)	1,135,000 (300,000)
Non-contact cooling	37,000 (9,600)	---	54,000 (14,000)	---

In facilities 2031 and 2032, the raw waste consists of the mill tailings emanating from the flotation step. In facility 2033, in addition to the mill tailings, the waste contains the primary thickener overflow and the filtrate from the product filtering operation. In facility 2044 the raw waste stream is the composite of the HMS tailings and the process waste stream from the scrubber. The average values given are listed as follows:

Waste Material at Facility No.	kg/kkg of flotation product (lb/1000 lb) 2031	2032	2033	2044
TSS	1800	1200-1750	800	26

NATURAL ABRASIVES

Garnet and tripoli are the major natural abrasives mined in the U.S. Other minor products, e.g. emery and special silica-stone products, are of such low volume production (2,500-3,000 kkg/yr) as to be economically insignificant and pose no significant environmental problems. They will not be considered further.

GARNET

Garnet is mined in the U.S. almost solely for use as an abrasive material. Two garnet abrasive producers, representing more than 80 percent of the total U.S. production, provided the data for this section. There are 4 facilities in the U. S. producing garnet, one of which produces it only as a by-product. The two garnet operations studied are in widely differing geographic locations, and so the garnet deposits differ, one being mountain schists (3071), and the other an alluvial deposit (3037).

Facility 3071 mines by open pit methods with standard drilling and blasting equipment. The ore is trucked to a primary crushing facility and from there conveyed to the mill where additional crushing and screening occurs. The screening produces the coarse feed to the heavy-media section and a fine feed for flotation. The heavy-media section produces a coarse tailing which is dewatered and stocked, a garnet concentrate, and a middling which is reground and sent to flotation. The garnet concentrate is then dewatered, filtered, and dried.

Facility 3037 mines shallow open pits, stripping off overburden, then using a dragline to feed the garnet-bearing earth to a trumble (heavy rotary screen). Large stones are recovered and used for road building or to refill the pits. The smaller stones are trucked to a jigging operation where the heavier garnet is separated from all impurities except for some of the high density kyanite. The raw garnet is then trucked to the mill. There the raw garnet is dried, screened, milled, screened and packaged. Figure 51 gives the general flow diagram for these operations.

Untreated surface water is pumped to the pits at facility 3037 for initial washing and screening operations and for make-up. This pit water is recycled and none is discharged except as ground water. Surface water is also used for the jigging operation, but is discharged after passage through a settling pond.

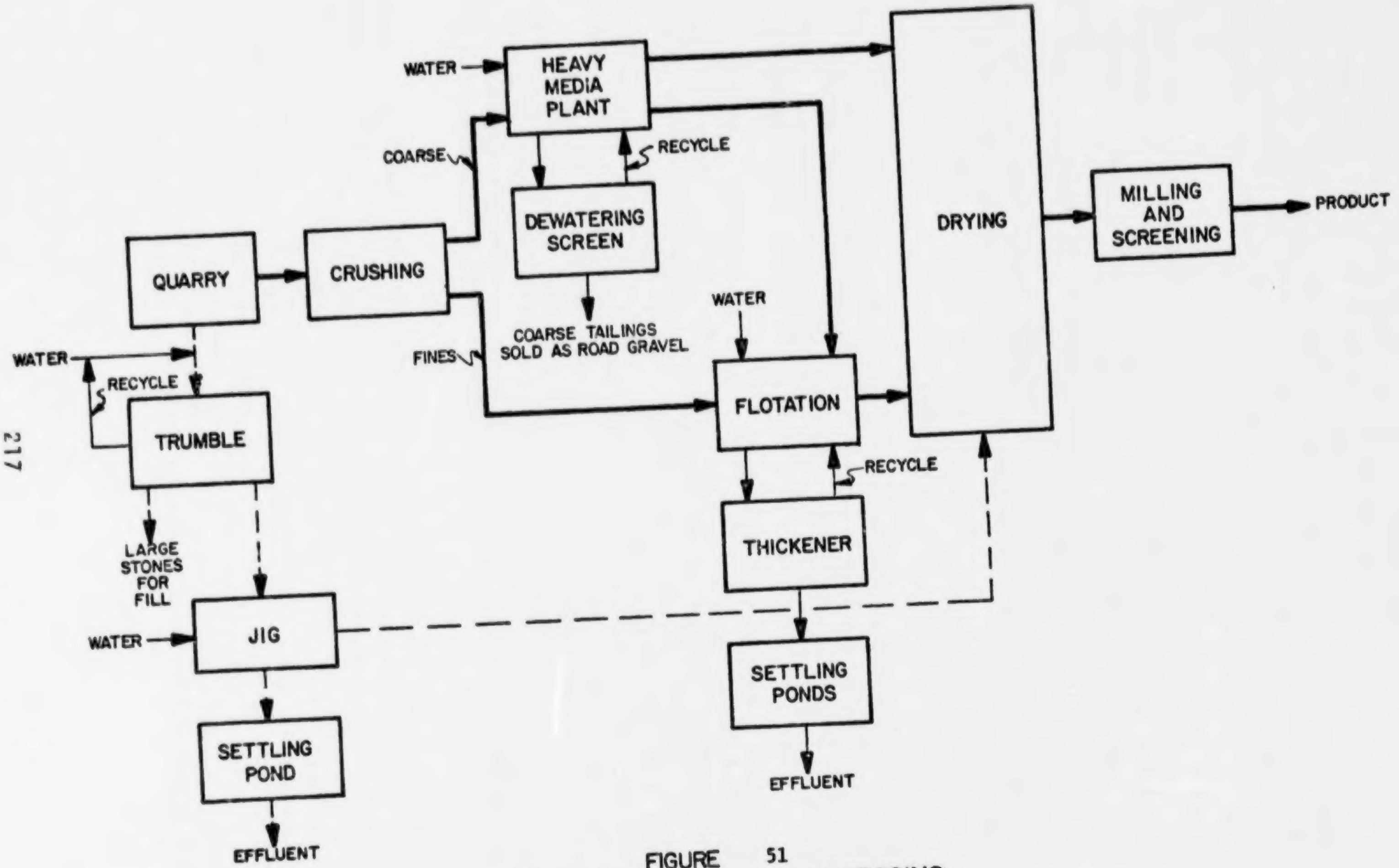

WATER
HEAVY MEDIA PLANT
COARSE
RECYCLE
DEWATERING SCREEN
QUARRY
CRUSHING
DRYING
MILLING AND SCREENING
PRODUCT
WATER
COARSE TAILINGS SOLD AS ROAD GRAVEL
FINES
WATER
RECYCLE
TRUMBLE
FLOTATION
RECYCLE
THICKENER
LARGE STONES FOR FILL
WATER
JIG
SETTLING PONDS
SETTLING POND
EFFLUENT
EFFLUENT

FIGURE 51
GARNET MINING AND PROCESSING

At facility 3071, water is collected from natural run-off and mine drainage into surface reservoirs, and 24,600 l/kkg (5,900 gal/ton) of product is used in both the heavy media and flotation units. This process water amounts to approximately 380-760 l/min (100-200 gpm) of which half is recycled. Effluent flow varies seasonally from a springtime maximum of 570 l/min (150 gpm) to a minimum in summer and fall.

In the processing of the garnet ore, solid waste in the form of coarse tailings is generated from the heavy-media facility at facility 3071. These tailings are stocked and sold as road gravel. The flotation underflow at facility 3071 consisting of waste fines, flotation reagents and water is first treated to stabilize the pH and then is sent to a series of tailings ponds. In these ponds, the solids settle and are removed intermittently by a dragline and used as landfill.

TRIPOLI

Tripoli encompasses a group of fine-grained, porous, silica materials which have similar properties and uses. These include tripoli, amorphous silica and rottenstone. All four producers of tripoli provided the data for this section.

Amorphous silica (tripoli) is normally mined from underground mines using conventional room-and-pillar techniques. There is at least one open-pit mine (5688). Trucks drive into the mines where they are loaded using front-end loaders. The ore is then transported to the facility for processing. Processing consists of crushing, screening, drying, milling, classifying, storage, and packing for shipping. A general process diagram is given in Figure 52. At one facility only a special grade tripoli (a minor portion of the production, value approximately $250,000/year) is made by a unique process using wet-milling and scrubbing.

There is no water used in mining, nor is there any ground water or rain water accumulation in the mines. The standard process is a completely dry process. Both facilities report no significant waste in processing. Any dust generated in screening, drying, or milling operations is gathered in cyclones and dust collectors and returned to the process as product. Mining generates a small amount of dirt which is piled outside the mine and gravel which is used to build roads in the mining areas. The product itself is of a very pure grade so no other mining wastes are generated.

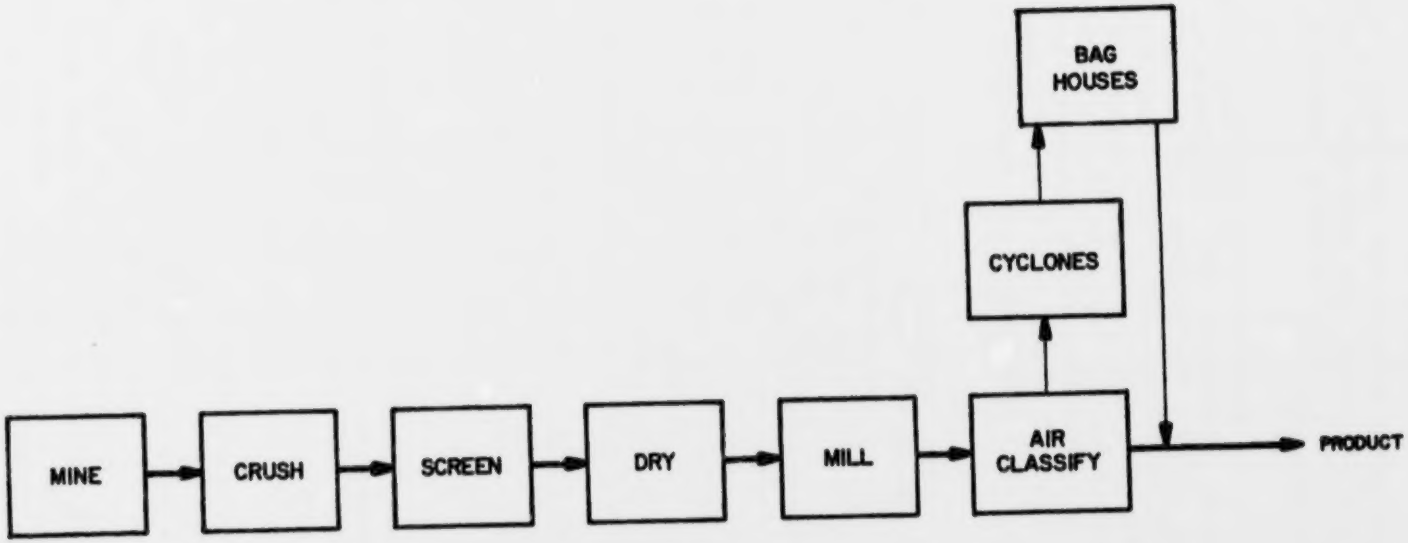

MINE
CRUSH
SCREEN
DRY
MILL
AIR CLASSIFY
CYCLONES
BAG HOUSES
PRODUCT

FIGURE 52
TRIPOLI MINING AND PROCESSING
BY THE STANDARD PROCESS

DIATOMITE MINING

There are nine diatomite mining and processing facilities in the U.S. The data from three are included in this section. These three facilities produce roughly one-half of the U.S. production of this material.

After the overburden is removed from the diatomite strata by power-driven shovels, scrapers and bulldozers, the crude diatomite is dug from the ground and loaded onto trucks. Facilities 5504 and 5505 haul the crude diatomite directly to the mills for processing. At facility 5500 the trucks carry the crude diatomite to vertical storage shafts placed in the formation at locations above a tunnel system. These shafts have gates through which the crude diatomite is fed to an electrical rail system for transportation to the primary crushers.

At facility 5500, after primary crushing, blending, and distribution, the material moves to different powder mill units. For "natural" or uncalcined powders, crude diatomite is crushed and then milled and dried simultaneously in a current of heated air. The dried powder is sent through separators to remove waste material and is further divided into coarse and fine fractions. These powders are then ready for packaging. For calcined powders, high temperature rotary kilns are continuously employed. After classifying, these powders are collected and packaged. To produce flux-calcined powders, particles are sintered together into microscopic clusters, then classified, collected and bagged.

At facilities 5504 and 5505, the ore is crushed, dried, separated and classified, collected, and stored in bins for shipping. Some of the diatomite is calcined at facility 5505 for a particular product. These processes are diagrammed in Figure 53.

One facility surface-quarries an oil-impregnated diatomite, which is crushed, screened, and calcined to drive off the oil. The diatomite is then cooled, ground, and packaged. In the future, the material will be heated and the oil vaporized and recovered as a petroleum product.

Water is used by facility 5500 in the principal process for dust collection and for preparing the waste oversize material for land disposal. In addition, a small amount of bearing cooling water is used. Water is used in the process at facility 5505 only in scrubbers used to cut down on dust fines in processing, which is recycled from settling ponds to the process. The only loss occurs through evaporation with make-up water added to the system. Water is used in

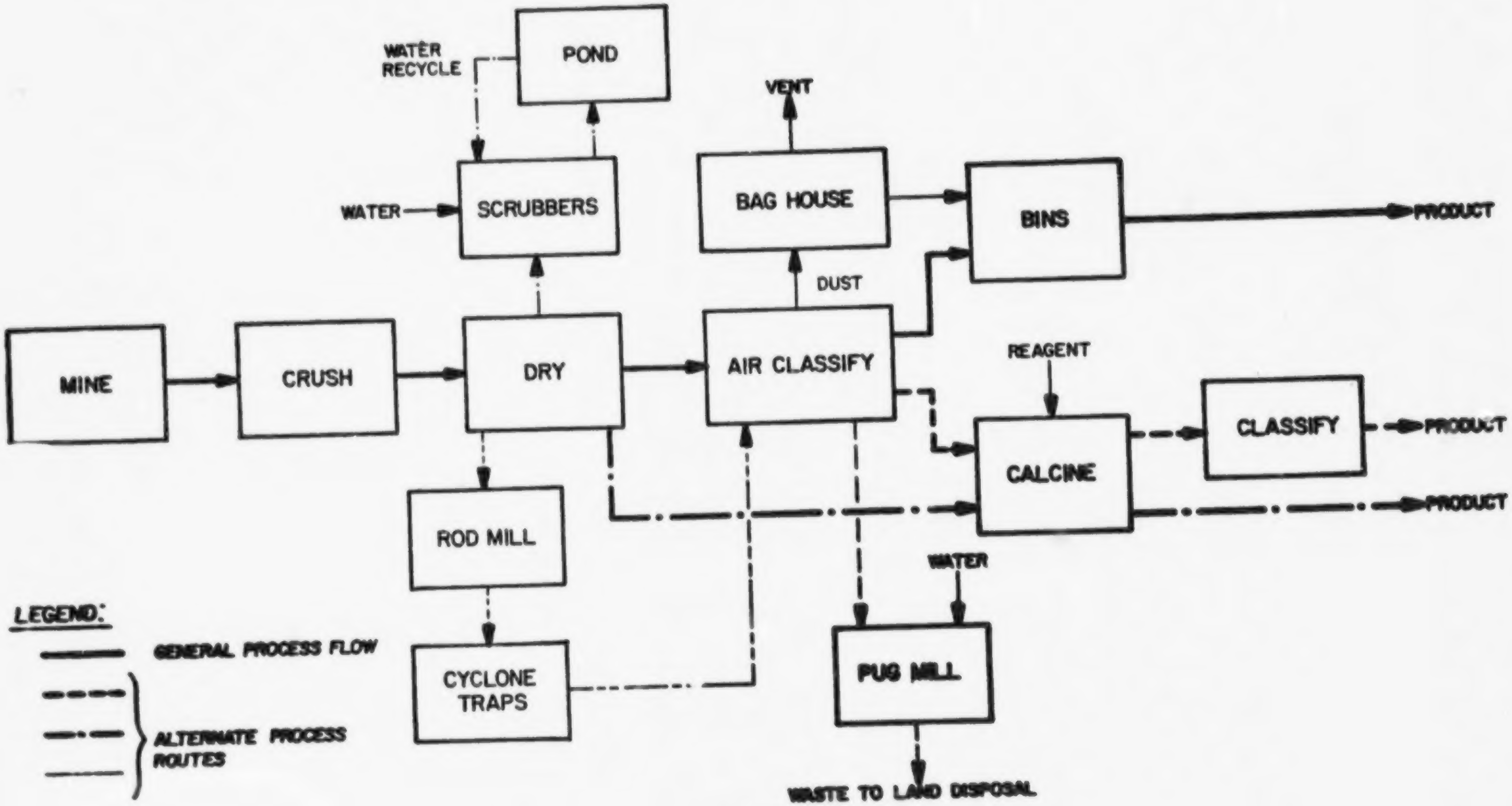

WATER RECYCLE
POND
VENT
WATER
SCRUBBERS
BAG HOUSE
BINS
PRODUCT
DUST
MINE
CRUSH
DRY
AIR CLASSIFY
REAGENT
CLASSIFY
PRODUCT
CALCINE
PRODUCT
ROD MILL
WATER
LEGEND:
GENERAL PROCESS FLOW
CYCLONE TRAPS
PUG MILL
ALTERNATE PROCESS ROUTES
WASTE TO LAND DISPOSAL

FIGURE 51
DIATOMITE MINING AND PROCESSING

the process at facility 5504 to slurry wastes to a closed pond. This water evaporates and/or percolates into the ground. As yet there is no recycle from the settling pond.

	l/kkg ore processed (gallon/ton)		
	5500	5505	5504
Intake:			
make-up water	2,800 (670)	880 (210)	3,800 (910)
Use:			
dust collection and waste disposal	2,670 (640)	8,700 (2,090)	3,800 (910)
bearing cooling	125-160 (30-38)	----	----
Consumption:			
evaporation (pond and process)	2,800 (670)	880 (210)	3,800 (910)

The much lower consumption of water at 5505 is due to the use of recycling from the settling pond to the scrubbers.

Wastes from these operations consist of the oversize waste fraction from the classifiers and of fines collected in dust control equipment. The amount is estimated to be 20 percent of the mined material at facility 5500, 16-19 percent at facility 5504 and 5-6 percent solids as a slurry from scrubber operations at facility 5505.

waste material	kg/kkg ore (lb/1000 lb)
Facility 5500, oversize, dust fines	200
Facility 5504, sand, rock, heavy diatoms	175
Facility 5505, dust fines (slurry)	45

GRAPHITE

There is one producer of natural graphite in the United States. The graphite ore is produced from an open pit using conventional mining methods of benching, breakage and removal. The ore is properly sized for flotation by passing through a 3-stage dry crushing and sizing system and then to a wet grinding circuit consisting of a rod mill in closed circuit with a classifier. Lime is added in the rod mill to adjust pH for optimum flotation. The classifier discharge is pumped to the flotation circuit where water additions are made and various reagents added at different points in the process flow. The graphite concentrate is floated, thickened, filtered and dried. The underflow or waste tailings from the cells are discharged as a slurry to a settling pond. The process flow diagram for the facility is shown in Figure 54.

The source of the intake water is almost totally from a lake. The exceptions are that the drinking water is taken from a well and a minimal volume for emergency or back-up for the process comes from an impoundment of an intermittent flowing creek. Some recycling of water takes place through the reuse of thickener overflow, filtrate from the filter operation and non-contact cooling water from compressors and vacuum pumps.

water consumption	l/metric tons of product (gal/ton)
total intake	159,000 (38,000)
process waste discharge	107,000 (26,000)
consumed (process, non-contact cooling, sanitation)	52,000 (12,000)

There are three sources of waste associated with the facility operation. They are the tailings from the flotation circuit (36,000 kg/kkg product), low pH seepage water from the tailings pond (19,000 l/kkg product) and an intermittent seepage from the mine. The flotation reagents used in this process are alcohols and pine oils.

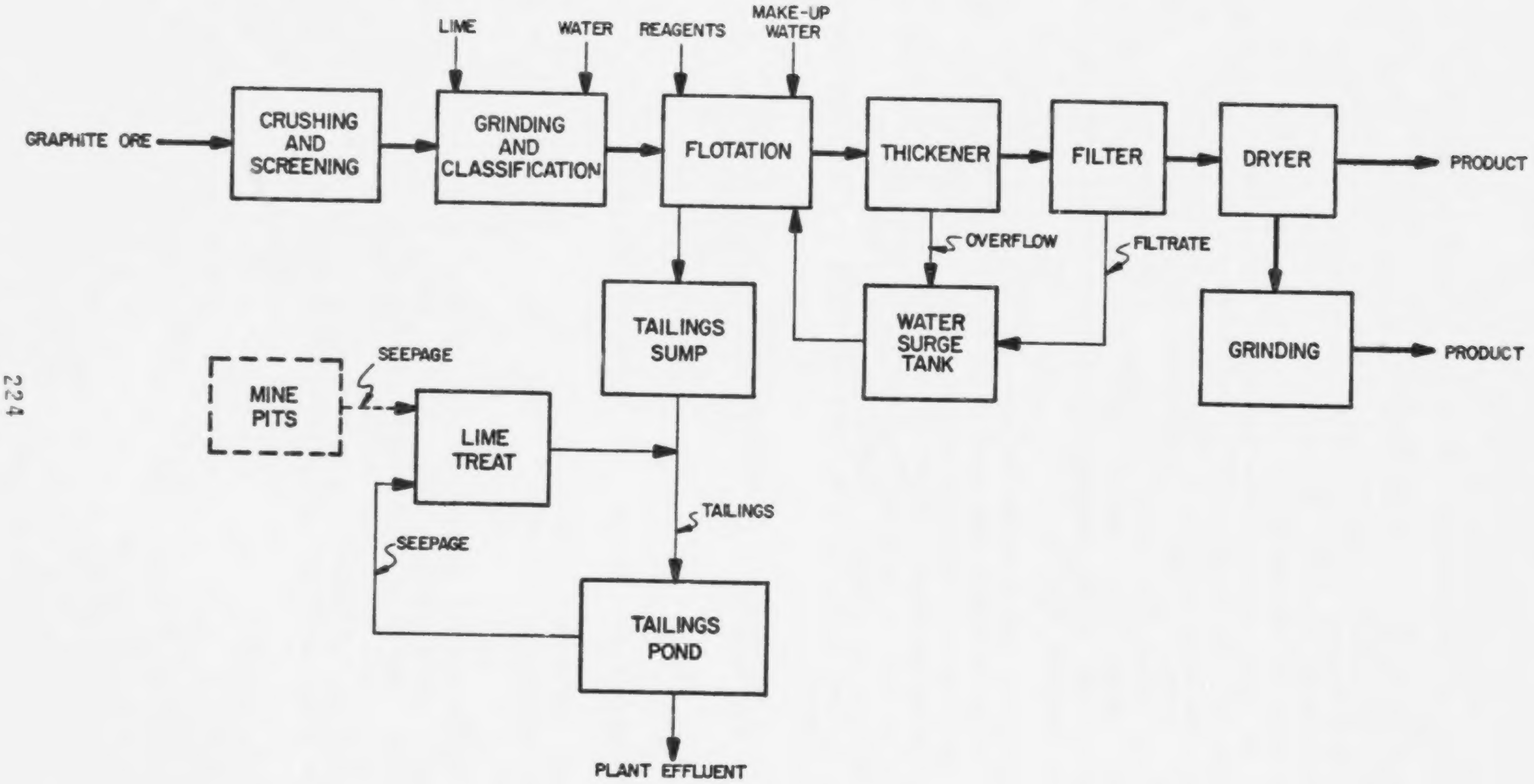

LIME
WATER
REAGENTS
MAKE-UP WATER
GRAPHITE ORE
CRUSHING AND SCREENING
GRINDING AND CLASSIFICATION
FLOTATION
THICKENER
FILTER
DRYER
PRODUCT
OVERFLOW
FILTRATE
TAILINGS SUMP
WATER SURGE TANK
GRINDING
PRODUCT
SEEPAGE
MINE PITS
LIME TREAT
TAILINGS
SEEPAGE
TAILINGS POND
PLANT EFFLUENT

FIGURE 54
GRAPHITE MINING AND PROCESSING

JADE

The jade industry in the U.S. is very small. One facility representing 55 percent of total U.S. jade production provided the data for this section.

The jade is mined in an open pit quarry, with rock being obtained by pneumatic drilling and wedging of large angular blocks. No explosives are used on the jade itself, only on the surrounding host rock. The rock is then trucked to the facility for processing. There the rock is sawed, sanded, polished and packaged for shipping. Of the material processed only a small amount (3 percent) is processed into gems and 47 percent is processed into floor and table tiles, grave markers, and artifacts. A general process diagram is given in Figure 55.

Well water is used in the process for the wire saw, sanding, and polishing operations. This water use amounts to 190 l/day (50 gpd) of which none is recycled. Approximately 50 percent of the rock taken each year from the quarry is unusable or unavoidably wasted in processing, amounting to 26.7 kkg/yr (29.5 tons/yr). There is no mine pumpout associated with this operation.

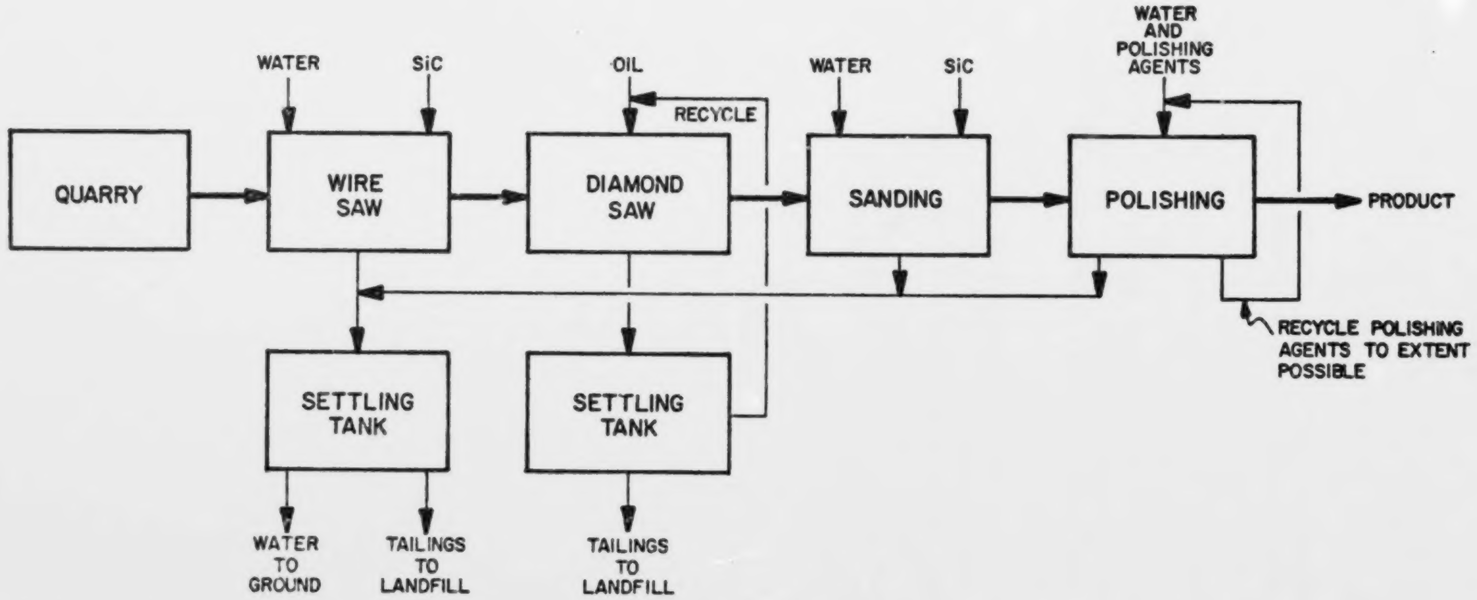

WATER
SiC
OIL
RECYCLE
WATER
SiC
WATER AND POLISHING AGENTS
QUARRY
WIRE SAW
DIAMOND SAW
SANDING
POLISHING
PRODUCT
RECYCLE POLISHING AGENTS TO EXTENT POSSIBLE
SETTLING TANK
SETTLING TANK
WATER TO GROUND
TAILINGS TO LANDFILL
TAILINGS TO LANDFILL

FIGURE 55
JADE MINING AND PROCESSING

NOVACULITE

Novaculite, a generic name for large geologic formations of pure, microcrystalline silica, is mined only in Arkansas by one facility. Open quarries are mined by drilling and blasting, with a front-end loader loading trucks for transport to covered storage at the facility. Since the quarry is worked for only about 2 weeks per year, mining is contracted out. Processing consists of crushing, drying, air classification and bagging. Normally silica will not require drying but novaculite is hydrophilic and will absorb water up to 9 parts per 100 of ore. Part of the air classifier product is diverted to a batch mixer, where organics are reacted with the silica for specialty products. A general process diagram is given in Figure 56.

No water is used in novaculite mining and the quarry is so constructed that no water accumulates. Total water usage at the facility for bearing cooling and the dust scrubber totals approximately 18,900 l/day (5,000 gpd) of city water. Of this total amount 7,300-14,500 l/day (1,900-3,800 gpd) is used for bearing cooling and an equivalent amount is used as make-up water to the dust scrubber.

Wastes generated in the mining of novaculite remain in the quarry as reclaiming fill, and processing generates only scrubber fines which are settled in a holding tank and eventually used for land-fill. However, a new facility dust scrubber will be installed with recycle of both water and fines.

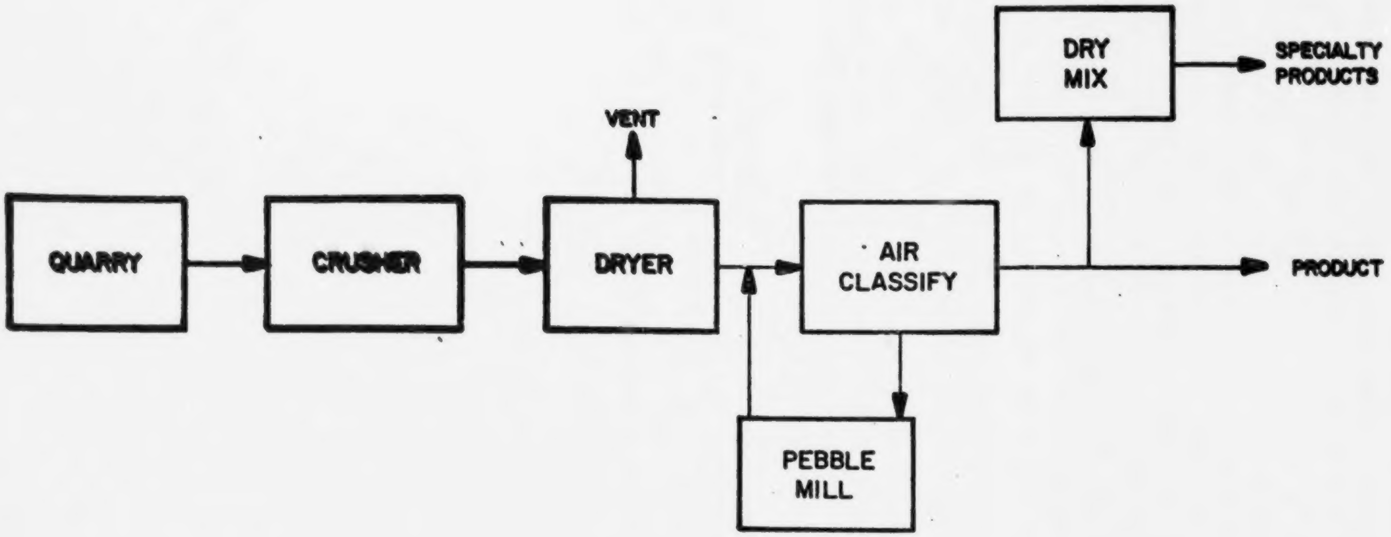

QUARRY
CRUSHER
DRYER
VENT
AIR CLASSIFY
PEBBLE MILL
DRY MIX
SPECIALTY PRODUCTS
PRODUCT

FIGURE 56
NOVACULITE MINING AND PROCESSING

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

Total suspended solids, dissolved solids, sulfide, iron, zinc, fluoride and pH were found to be the major waste water pollutant parameters.

DISSOLVED SOLIDS

Total dissolved solids are a gross measure of the amount of soluble pollutants in the waste water. It is an important parameter in drinking water supplies and water used for irrigation. Dissolved solids are found in significant quantities in rock salt, brine and trona operations. In natural waters the dissolved solids consist mainly of carbonates, chlorides, sulfates, phosphates, and possibly nitrates of calcium, magnesium, sodium and potassium, with traces of iron, manganese and other substances.

Some communities in the United States and in other countries use water supplies containing 2,000 to 4,000 mg/liter of dissolved salts, when no better water is available. Such waters are not palatable, may not quench thirst, and may have a laxative action on new users. Waters containing more than 4,000 mg/liter of total salts are generally considered unfit for human use, although in hot climates such higher salt concentrations can be tolerated whereas they could not be in temperate climates. Waters containing 5,000 mg/liter or more are reported to be bitter and act as bladder and intestinal irritants. It is generally agreed that the salt concentration of good, palatable water should not exceed 500 mg/liter.

Limiting concentrations of dissolved solids for fresh-water fish may range from 5,000 to 10,000 mg/liter, according to species and prior acclimatization. Some fish are adapted to living in more saline waters, and a few species of fresh-water forms have been found in natural waters with a salt concentration of 15,000 to 20,000 mg/liter. Fish can slowly become acclimatized to higher salinities, but fish in waters of low salinity cannot survive sudden exposure to high salinities, such as those resulting from discharges of oil-well brines. Dissolved solids may influence the toxicity of heavy metals and organic compounds to fish and other aquatic life, primarily because of the antagonistic effect of hardness on metals. Water with total dissolved solids over 500 mg/liter water has little or no value for irrigation. Dissolved solids in industrial waters can cause foaming in boilers and cause interference with cleanness, color, or taste of many finished products. High concentrations of dissolved solids also tend to accelerate corrosion.

Dissolved solids are only regulated in cases where no discharge of pollutants is specified. This is usually by means of solar evaporation, total recycle or covered storage facilities. Reduction of TDS by other means such as ion exchange is judged to be economically infeasible.

FLUORIDE

Fluorine is the most reactive of the nonmetals and is never found free in nature. It is a constituent of fluorite or fluorspar, calcium fluoride, cryolite, and sodium aluminum fluoride. Due to their origins, fluorides in high concentrations are not a common constituent of natural surface waters; however, they may occur in hazardous concentrations in ground waters.

Fluoride can be found in plating rinses and in glass etching rinse waters. Fluorides are also used as a flux in the manufacture of steel, for preserving wood and mucilages, as a disinfectant and in insecticides.

Fluorides in sufficient quantities are toxic to humans with doses of 250 to 450 mg giving severe symptoms and 4.0 grams causing death. A concentration of 0.5 g/kg of body weight has been reported as a fatal dosage.

There are numerous articles describing the effects of fluoride-bearing waters on dental enamel of children; these studies lead to the generalization that water containing less than 0.9 to 1.0 mg/l of fluoride will seldom cause mottled enamel in children, and for adults, concentrations less than 3 or 4 mg/l are not likely to cause endemic cumulative fluorosis and skeletal effects. Abundant literature is also available describing the advantages of maintaining 0.8 to 1.5 mg/l of fluoride ion in drinking water to aid in the reduction of dental decay, especially among children. The recommended maximum levels of fluoride in public water supply sources range from 1.4 to 2.4 mg/l.

Fluorides may be harmful in certain industries, particularly those involved in the production of food, beverages, pharmaceutical, and medicines. Fluorides found in irrigation waters in high concentrations (up to 360 mg/l) have caused damage to certain plants exposed to these waters. Chronic fluoride poisoning of livestock has been observed in areas where water contained 10 to 15 mg/l fluoride. Concentrations of 30 - 50 mg/l of fluoride in the total ration of dairy cows are considered the upper safe limit. Fluoride from waters apparently does not accumulate in soft tissue to a significant degree and it is transferred to a very small extent into the milk and to a somewhat greater degree into eggs. Data for fresh water indicate that fluorides are toxic to fish at concentrations higher than 1.5 mg/l.

Fluoride is found in the industrial sand, fluorspar and feldspar subcategories.

pH

Although not a specific pollutant, pH is related to the acidity or alkalinity of a waste water stream. It is not a linear or direct measure of either, however, it may properly be used as a surrogate to control both excess acidity and excess alkalinity in water. The term pH is used to describe the hydrogen ion - hydroxyl ion balance in water. Technically, pH is the hydrogen ion concentration or activity present in a given solution. pH numbers are the negative logarithm of the hydrogen ion concentration. A pH of 7 generally indicates neutrality or a balance between free hydrogen and free hydroxyl ions. Solutions with a pH above 7 indicate that the solution is alkaline, while a pH below 7 indicate that the solution is acid.

Knowledge of the pH of water or waste water is useful in determining necessary measures for corrosion control, pollution control, and disinfection. Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and such corrosion can add constituents to drinking water such as iron, copper, zinc, cadmium, and lead. Low pH waters not only tend to dissolve metals from structures and fixtures but also tend to redissolve or leach metals from sludges and bottom sediments. The hydrogen ion concentration can affect the "taste" of the water and at a low pH, water tastes "sour".

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. For example, metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. Similarly, the toxicity of ammonia is a function of pH. The bactericidal effect of chlorine in most cases is less as the pH increases, and it is economically advantageous to keep the pH close to 7.

TOTAL SUSPENDED SOLIDS

Suspended solids include both organic and inorganic materials. The inorganic compounds include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, and animal and vegetable waste products. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic plants.

Suspended solids in water interfere with many industrial processes, cause foaming in boilers and incrustations on equipment exposed to such water, especially as the temperature rises. They are undesirable in process water used in the manufacture of steel, in the textile industry, in laundries, in dyeing and in cooling systems.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often damaging to the life in water. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a food source for sludgeworms and associated organisms.

Disregarding any toxic effect attributable to substances leached out by water, suspended solids may kill fish and shellfish by causing abrasive injuries and by clogging the gills and respiratory passages of various aquatic fauna. Indirectly, suspended solids are inimical to aquatic life because they screen out light, and they promote and maintain the development of noxious conditions through oxygen depletion. This results in the killing of fish and fish food organisms. Suspended solids also reduce the recreational value of the water.

Total suspended solids are the single most important pollutant parameter found in the mineral mining and processing industry.

TURBIDITY

Turbidity of water is related to the amount of suspended and colloidal matter contained in the water. It affects the clearness and penetration of light. The degree of turbidity is only an expression of one effect of suspended solids upon the character of the water. Turbidity can reduce the effectiveness of chlorination and can result in difficulties in meeting BOD and suspended solids limitations. Turbidity is an indirect measure of suspended solids.

SULFIDES

Sulfides may be present in significant amounts in the wastewater from the manufacture of rock salt and sulfur facilities. Concentrations in the range of 1.0 to 25.0 mg/l of sulfides may be lethal in 1 to 3 days to a variety of fresh water fish.

IRON (Fe)

Iron is an abundant metal found in the earth's crust. The most common iron ore is hematite from which iron is obtained by reduction with carbon. Other forms of commercial ores are magnetite and taconite. Pure iron is not often found in commercial use, but it is usally alloyed with other metals and minerals, the most common being carbon.

Iron is the basic element in the production of steel and steel alloys. Iron with carbon is used for casting of major parts of machines and it can be machined, cast, formed, and welded. Ferrous iron is used in paints, while powdered iron can be sintered and used in powder metallurgy. Iron compounds are also used to precipitate other metals and undesirable minerals from industrial waste water streams.

Iron is chemically reactive and corrodes rapidly in the presence of moist air and at elevated temperatures. In water and in the presence of oxygen, the resulting products of iron corrosion may be pollutants in water. Natural pollution occurs from the leaching of soluble iron salts from soil and rocks and is increased by industrial waste water from pickling baths and other solutions containing iron salts.

Corrosion products of iron in water cause staining of porcelain fixtures, and ferric iron combines with the tannin to produce a dark violet color. The presence of excessive iron in water discourages cows from drinking and, thus, reduces milk production. High concentrations of ferric and ferrous ions in water kill most fish introduced to the solution within a few hours. The killing action is attributed to coatings of iron hydroxide precipitates on the gills. Iron oxidizing bacteria are dependent on iron in water for growth. These bacteria form slimes that can affect the esthetic values of bodies of water and cause stoppage of flows in pipes.

Iron is an essential nutrient and micronutrient for all forms of growth. Drinking water standards in the U. S. have set a recommended limit of 0.3 mg/l of iron in domestic water supplies based not on the physiological considerations, but rather on aesthetic and taste considerations of iron in water.

ZINC

Occurring abundantly in rocks and ores, zinc is readily refined into a stable pure metal and is used extensively as a metal, an alloy, and a plating material. In addition, zinc salts are also used in paint pigments, dyes, and insecticides. Many of these salts (for example, zinc chloride and zinc sulfate) are highly soluble in water; hence, it is expected that zinc might occur in many industrial wastes. On the other hand, some zinc salts (zinc carbonate, zinc oxide, zinc sulfide) are insoluble in water and, consequently, it is expected that some zinc will precipitate and be removed readily in many natural waters.

In soft water, concentrations of zinc ranging from 0.1 to 1.0 mg/l have been reported to be lethal to fish. Zinc is thought to exert its toxic action by forming insoluble compounds with the mucous that covers the gills, by damage to the gill epithelium, or possibly by acting as an internal poison. The sensitivity of fish to zinc varies with species, age, and condition, as well as with the physical and chemical characteristics of the water. Some acclimatization to the presence of the zinc is possible. It has also been observed that the effects of zinc poisoning may not become apparent immediately so that fish removed from zinc-contaminated to zinc-free water may die as long as 48 hours after the removal. The presence of copper in water may increase the toxicity of zinc to aquatic organisms, while the presence of calcium or hardness may decrease the relative toxicity. A complex relationship exists between zinc concentrations, dissolved oxygen, pH, temperature, and calcium and magnesium concentrations. Prediction of harmful effects has been less than reliable and controlled studies have not been extensively documented.

Concentrations of zinc in excess of 5 mg/l in public water supply sources cause an undesirable taste which persists through conventional treatment. Zinc can have an adverse effect on man and animals at high concentrations. Observed values for the distribution of zinc in ocean waters varies widely. The major concern with zinc compounds in marine waters is not one of actute lethal effects, but rather one of the long term sublethal effects of the metallic compounds and complexes. From the point of view of accute lethal effects, invertebrate marine animals seem to be the most sensitive organisms tested. A variety of freshwater plants tested manifested harmful symptoms at concentrations of 10 mg/l. Zinc sulfate has also been found to be lethal to many plants and it could impair agricultural uses of the water.

SIGNIFICANCE AND RATIONALE FOR REJECTION OF POLLUTION PARAMETERS

A number of pollution parameters were studied but were not found to be significant because of the following reasons:

(1) they are not usually present in quantities sufficient to cause water quality degradation;
(2) treatment does not "practicably" reduce the parameter; or
(3) simultaneous reduction is achieved with another parameter which is limited.

TOXIC MATERIALS

Although arsenic, antimony, barium, boron, cadmium, chromium, copper, cyanide ion, manganese, mercury, nickel, lead, selenium, and tin are harmful pollutants, they were not found in significant quantities.

TEMPERATURE

Excess thermal load, even in non-contact cooling water, has not been found to be a significant problem in this segment of the mineral mining and processing industry.

ASBESTOS

"Asbestos" is a generic term for a number of fire-resistant hydrated silicates that, when crushed or processed, separate into flexible fibers made up of fibrils noted for their great tensile strength. Although there are many asbestos minerals, only five are of commercial importance. Chrysotile, a tubular serpentine mineral, accounts for 95 percent of the world's production. The others, all amphiboles, are amosite, crocidolite, anthophyllite, and tremolite. The asbestos minerals differ in their metallic elemental content, range of fiber diameters, flexibility or hardness, tensile strength, surface properties, and other attributes that determine their industrial uses and may affect their respirability, deposition, retention, translocation, and biologic reactivity. Serpentine asbestos is a magnesium silicate the fibers of which are strong and flexible so that spinning is possible with the longer fibers. Amphibole asbestos includes various silicates of magnesium, iron, calcium, and sodium. The fibers are generally brittle and cannot be spun but are more resistant to chemicals and to heat than serpentine asbestos.

Chrysotile	$3MgO \cdot 2SiO_2 \cdot 2H_2O$
Anthophyllite	$(FeMg) \cdot SiO_3 \cdot H_2O$
Amosite	(ferroanthophyllite)
Crocidolite	$NaFe \cdot (SiO_3)_2 \cdot FeSiO_3 \cdot H_2O$
Tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$

All epidemiologic studies that appear to indicate differences in pathogenicity among types of asbestos are flawed by their lack of quantitative data on cumulative exposures, fiber characteristics, and the presence of cofactors. The different types, therefore, cannot be graded as to relative risk with respect to asbestosis. Fiber size is critically important in determining respirability, deposition, retention, and clearance from the pulmonary tract and is probably an important determinant of the site and nature of biologic action. Little is known about the movement of the fibers within the human body, including their potential for entry through the gastrointestinal tract. There is evidence though that bundles of fibrils may be broken down within the body to individual fibrils. However, methods which are technically and economically practicable for most operations for removing asbestos from effluents are not available.

RADIATION AND RADIOACTIVITY

Exposure to ionizing radiation at levels substantially above that of general background levels can be harmful to living organisms. Such exposure may cause adverse somatic effects such as cancer and life shortening as well as genetic damage. At environmental levels that may result from releases by industries processing materials containing natural radionuclides, the existence of such adverse effects has not been verified. Nevertheless, it is generally agreed that the prudent public health policy is to assume a non-threshold health effect response to radiation exposure.

Furthermore, a linear response curve is generally assumed which enables the statistical estimate of risk from observed values at higher exposures to radiation through to zero exposure.

The half-life of the particular radionuclides released to the environment by an industry is extremely important in determining the significance of such releases. Once released to the biosphere, radionuclides with long half-lives can persist for hundreds and thousands of years. This fact coupled with their possible buildup in the environment can lead to their being a source of potential population exposure for many hundreds of years. Therefore, in order to minimize the potential impact of these radionuclides, they must be excluded from the biosphere as much as possible.

Facilities and animals that incorporate radioactivity through the biological cycle can pose a health hazard to man through the food chain. Facilities and animals, to be of significance in the cycling of radionuclides in the aquatic environment must assimilate the radionuclide, retain it, be eaten by another organism, and be digestible. However, even if an organism is not eaten before it dies, the radionuclide will remain in the biosphere continuing as a potential source of exposure.

Aquatic life may assimilate radionuclides from materials present in the water, sediment, and biota. Humans can assimilate radioactivity through many different pathways. Among them are drinking contaminated water, and eating fish and shellfish that have radionuclides incorporated in them. Where fish or other fresh or maring products that may accumulate radioactive materials are used as food by humans, the concentrations of the radionuclides in the water must be restricted to provide assurance that the total intake of radionuclides from all sources will not exceed recommended levels.

RADIUM 226

Radium 226 is a member of the uranium decay series. It has a half-life of 1620 years. This radionuclide is naturally present in soils throughout the United States in concentrations ranging from 0.15 to 2.8 picocuries per gram. It is also naturally present in ground waters and surface streams in varying concentrations. Radium 226 is present in minerals in the earth's crust. Generally, minerals contain varying concentrations of radium 226 and its decay products depending upon geological methods of deposition and leaching action over the years. The human body may incorporate radium in bone tissue in lieu of calcium. Some facilities

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and animals concentrate radium which can significantly impact the food chain.

As a result of its long half-life, radium 226 which was present in minerals extracted from the earth may persist in the biosphere for many years after introduction through effluents or wastes. Therefore, because of its radiological consequences, concentrations of this radionuclide need to be restricted to minimize potential exposure to humans.

Relatively low concentrations of radioactivity and radium 226 were found in the treated effluent for the phosphate industry. Although available treatment is specific for suspended solids and not radium,removal of TSS results in removal of the latter. Therefore, limitations based on treatment for TSS rather than specifically for radium 226 are felt to be appropriate at this time.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

Waste water pollutants from the mining of minerals for the construction industry consist primarily of suspended solids. These are usually composed of chemically inert and very insoluble sand, clay or rock particles. Treatment technology is well developed for removing such particles from waste water and is readily applicable whenever space requirements or economics do not preclude utilization.

In a few instances dissolved substances such as fluorides, acids, alkalies, and chemical additives from ore processing may also be involved. Where they are present, dissolved material concentrations are usually low. Treatment technology for the dissolved solids is also well-known, but may often be limited by the large volumes of waste water involved and the cost of such large scale operations.

The control and treatment of the pollutants found in this industry are complicated by several factors:

(1) the large volumes of waste water involved for many of the processing operations,

(2) the variable waste water quantities and composition from day to day, as influenced by rainfall and other surface and underground water contributions,

(3) differences in waste water compositions arising from ore or raw material variability,

(4) geographical location: e.g., waste water can be handled differently in dry isolated locations than in industrialized wet climates.

Control practices such as selection of raw materials, good housekeeping, minimizing leaks and spills, in-process changes, and segregation of process waste water streams are not as important in the minerals industry as they are in more process-oriented manufacturing operations. Raw materials are fixed by the composition of the ore available; good housekeeping and small leaks and spills have little influence on the waste loads; and it is uncommon that any noncontact cooling water, is involved in minerals mining and processing. There are a number of areas, however, where control is very important.

Separation and Control of Waste water

In these industries waste water may be separated into different categories:

(1) Mine dewatering. For many mines this is the only effluent. Usually it is low in suspended solids, but may contain dissolved minerals.

(2) Process water. This is water involved in transporting, classifying, washing, beneficiating, and separating ores and other mined materials. This water usually contains heavy loads of suspended solids and possibly some dissolved materials.

(3) Rain water runoff. Since mineral mining operations often involve large surface areas, the rain water that falls on the mine and process facility property constitutes a major portion of the overall waste water load leaving the property. This water entrains minerals, silt, sand, clay, organic matter and other suspended solids.

The relative amounts and compositions of the above waste water streams differ from one mining category to another and the separation, control and treatment techniques differ for each.

Process water and mine dewatering is normally controlled and contained by pumping or gravity flow through pipes, channels, ditches and ponds. Rain water runoff, on the other hand, is often uncontrolled and may contaminate process and mine dewatering water or flow off the land independently as non-point discharges.

Degradation of the mine water quality may be caused by combining the wastewater streams for treatment at one location. A negative effect results because water with low pollutant loading (often the mine water) serves to dilute water of higher pollutant loading. This often results in decreased water treatment efficiency because concentrated waste streams can often be treated more effectively than dilute waste streams. The mine water in these cases may be treated by relatively simple methods; while the volume of waste water treated in the process facility impoundment system will be reduced, this water will be treated with increased efficiency.

Surface runoff in the immediate area of beneficiation facilities presents another potential pollution problem. Runoff from haul roads, areas near conveyors, and ore storage piles is a potential source of pollutant loading to nearby surface waters. Several current industry practices to control this pollution are:

(1) Construction of ditches surrounding storage areas to divert surface runoff and collect seepage that does occur.

(2) Establishment of a vegetative cover of grasses in areas of potential sheet wash and erosion to stabilize the material, to control erosion and sedimentation, and to improve the aesthetic aspects of the area.

(3) Installation of hard surfaces on haul roads, beneath conveyors, etc., with proper slopes to direct drainage to a sump. Collected waters may be pumped to an existing treatment facility for treatment.

Another potential problem associated with construction of tailing-pond treatment systems is the use of existing valleys and natural drainage areas for impoundment of mine water or process waste water. The capacity of these impoundment systems frequently is not large enough to prevent high discharge flow rates, particularly during the late winter and early spring months. The use of ditches, flumes, pipes, trench drains, and dikes will assist in preventing runoff caused by snowmelt, rainfall, or streams from entering impoundments. Very often, this runoff flow is the only factor preventing attainment of zero discharge. Diversion of natural runoff from impoundment treatment systems, or construction of these facilities in locations which do not obstruct natural drainage, is therefore, desirable.

Ditches may be constructed upslope from the impoundment to prevent water from entering it. These ditches also convey water away and reduce the total volume of water which must be treated. This may result in decreased treatment costs, which could offset the costs of diversion.

MINING TECHNIQUES

Mining techniques can effectively reduce amounts of pollutants coming from a mine area by containment within the mine area or by reducing their formation. These techniques can be combined with careful reclamation planning and implementation to provide maximum at-source pollution control. Several techniques have been implemented to reduce environmental degradation during strip-mining operations.

Utilization of the box-cut technique in moderate- and shallow-slope contour mining has increased recently because more stringent environmental controls are being implemented.

A box cut is simply a contour strip mine in which a low-wall barrier is maintained. Spoil may be piled on the low wall side. This technique significantly reduces the amount of water discharged from a pit area, since that water is prevented from seeping through spoil banks. The problems of preventing slides, spoil erosion, and resulting stream sedimentation are still present, however.

Block-cut mining was developed to facilitate regrading, minimize overburden handling, and contain spoil within mining areas. In block-cut mining, contour stripping is typically accomplished by throwing spoil from the bench onto downslope areas. This downslope material can slump or rapidly erode and must be moved upslope to the mine site if contour regrading is desired. The land area affected by contour strip mining is substantially larger than the area from which the ores are extracted. When using block-cut mining, only material from the first cut is deposited in adjacent low areas. Remaining spoil is then placed in mined portions of the bench. Spoil handling is restricted to the actual pit area for all areas but the first cut, which significantly reduces the area disturbed.

Pollution-control technology in underground mining is largely restricted to at-source methods of reducing water influx into mine workings. Infiltration from strata surrounding the workings is the primary source of water, and this water reacts with air and sulfide minerals within the mines to create acid pH conditions and, thus, to increase the potential for solubilization of metals. Underground mines are, therefore, faced with problems of water handling and mine-drainage treatment. Open-pit mines, on the other hand, receive both direct rainfall and runoff contributions, as well as infiltrated water from intercepted strata.

Infiltration in underground mines generally results from rainfall recharge of a ground-water reservoir. Rock fracture zones, joints, and faults have a strong influence on ground-water flow patterns since they can collect and convey large volumes of water. These zones and faults can intersect any portion of an underground mine and permit easy access of ground water. In some mines, infiltration can result in huge volumes of water that must be handled and treated. Pumping can be a major part of the mining operation in terms of equipment and expense--particularly, in mines which do not discharge by gravity.

Water-infiltration control techniques, designed to reduce the amount of water entering the workings, are extremely important in underground mines located in or adjacent to water-bearing strata. These techniques are often employed in such mines to decrease the volume of water requiring handling and treatment, to make the mine workable, and to control energy costs associated with dewatering. The techniques include pressure grouting of fissures which are entry points for water into the mine. New polymer-based grouting materials have been developed which should improve the effectiveness of such grouting procedures. In severe cases, pilot holes can be drilled ahead of actual mining areas to determine if excessive water is likely to be encountered. When water is encountered, a small pilot hole can be easily filled by pressure grouting, and mining activity may be directed toward non-water-contributing areas in the formation. The feasibility of such control is a function of the structure of the ore body, the type of surrounding rock, and the characteristics of ground water in the area.

Decreased water volume, however, does not necessarily mean that waste water pollutant loading will also decrease. In underground mines oxygen, in the presence of humidity, interacts with minerals on the mine walls and floor to permit pollutant formation e.g., acid mine water, while water flowing through the mine transports pollutants to the outside. If the volume of this water is decreased but the volume of pollutants remains unchanged, the resultant smaller discharge will contain increased pollutant concentrations, but approximately the same pollutant load. Rapid pumpout of the mine can, however, reduce the contact time and significantly reduce the formation of pollutants.

Reduction of mine discharge volume can reduce water handling costs. In cases of acid mine drainage, for example, the same amounts of neutralizing agents will be required because pollutant loads will remain unchanged. The volume of mine water to be treated, however, will be reduced significantly, together with the size of the necessary treatment and settling facilities. This cost reduction, along with cost savings which can be attributed to decreased pumping volumes (hence, smaller pumps, lower energy requirements, and smaller treatment facilities), makes use of water infiltration-control techniques highly desirable.

Water entering underground mines may pass vertically through the mine roof from rock formations above. These rock units may have well-developed joint systems (fractures along which no movement occurs), which tend to facilitate vertical flow. Roof collapses can also cause widespread fracturing in overlying rocks, as well as joint separation far above the mine roof. Opened joints may channel flow from overlying aquifers (water-bearing rocks), a flooded mine above, or even from the surface.

Fracturing of overlying strata is reduced by employing any or all of several methods: (1) Increasing pillar size; (2) Increasing support of the roof; (3) Limiting the number of mine entries and reducing mine entry widths; (4) Backfilling of the mined areas with waste material.

Surface mines are often responsible for collecting and conveying large quantities of surface water to adjacent or underlying underground mines. Ungraded surface mines often collect water in open pits when no surface discharge point is available. That water may subsequently enter the groundwater system and then percolate into an underground mine. The influx of water to underground mines from either active or abandoned surface mines can be significantly reduced through implementation of a well-designed reclamation plan.

The only actual underground mining technique developed specifically for pollution control is preplanned flooding. This technique is primarily one of mine design, in which a mine is planned from its inception for post-operation flooding or zero discharge. In drift mines and shallow slope or shaft mines, this is generally achieved by working the mine with the dip of the rock (inclination of the rock to the horizontal) and pumping out the water which collects in the shafts. Upon completion of mining activities, the mine is allowed to flood naturally, eliminating the possibility of acid formation caused by the contact between sulfide minerals and oxygen. Discharges, if any, from a flooded mine should contain a much lower pollutant concentration. A flooded mine may also be sealed.

SUSPENDED SOLIDS REMOVAL

The treatment technologies available for removing suspended solids from minerals mining and processing waste water are numerous and varied, but a relatively small number are widely used. The following shows the approximate breakdown of usage for the various techniques:

removal technique	percent of treatment facilities using technology
settling ponds (unlined)	95-97
settling ponds (lined)	<1
chemical flocculation (usually with ponds)	2-5
thickeners and clarifiers	2-5
hydrocyclones	<1
tube and lamella settlers	<1
screens	<1
filters	<1
centrifuges	<1

SETTLING PONDS

As shown above, the predominant treatment technique for removal of suspended solids involves one or more settling ponds. Settling ponds are versatile in that they perform several waste-oriented functions including:

(1) Solids removal. Solids settle to the bottom and the clear water overflow is much reduced in suspended solids content.

(2) Equalization and water storage capacity. The clear supernatant water layer serves as a reservoir for reuse or for controlled discharge.

(3) Solid waste storage. The settled solids are provided with long term storage.

This versatility, ease of construction and relatively low cost, explains the wide application of settling ponds as compared to other technologies. The performance of these ponds depends primarily on the settling characteristics of the suspended solids, the flow rate through the pond and the pond size. Settling ponds can be used over a wide range of suspended solids levels. Often a series of ponds is used, with the first collecting the heavy load of easily settled material and the following ones providing final polishing to reach a desired suspended solids level. As the ponds fill with solids they can be dredged to remove these solids or they may be left filled and new ponds provided. The choice often depends on whether land for additional new ponds is available. When suspended solids levels are low and ponds large, settled solids build up so slowly that neither dredging nor pond abandonment is necessary, at least not for a period of many years.

Settling ponds used in the minerals industry range from small pits, natural depressions and swamp areas to engineered thousand acre structures with massive retaining dams and legislated construction design. The performance of these ponds can vary from excellent to poor, depending on character of the suspended particles, and pond size and configuration.

In general the current experience in this industry segment with settling ponds shows reduction to 50 mg/l or less, but for some waste waters the discharge may still contain up to 150 mg/l of TSS. Performance data of some settling ponds found in the dimension stone, crushed stone, construction sand and gravel, and industrial sand subcategories is given in Table 12. Eighteen of these 20 facility samples show greater than 95 percent reduction of TSS by ponding. There appear to be no correlations within a sampled subcategory due to differences in quality of intake water, mined product, or processing. Laboratory settling data collected on samples of the process waste water pond from six of the sand and gravel facilities contained in the above data show that under controlled conditions they can be settled within 24 hours to a range of 20-450 mg/l of suspended solids, and, with the addition of commercial coagulant can be settled to a range of 10-60 mg/l in the same time period. These laboratory data are consistent with the pond performance measured above.

In this industry, settling is usually a prelude to recycle of water for washing purposes. The level of suspended solids commonly viewed as acceptable in recycled water used for construction materials washing is 200 mg/l and higher. Every facility in the above sample achieved this level with values ranging from 3 to 154 mg/l. Thus the TSS levels obtained after settling in ponds are apparently under present practices adequate for recycling purposes for these subcategories.

Much of the poor performance exhibited by the settling ponds employed by the minerals industry is due to the lack of understating of settling techniques. This is demonstrated by the construction of ponds without prior determination of settling rate and detention time. In some cases series of ponds have been claimed to demonstrate a company's mindfullness of environmental control when in fact all the component ponds are so poorly constructed and maintained that they could be effectively replaced by one pond with less surface area than the total of the series.

The chief problems experienced by settling ponds are rapid fill-up, insufficient retention time and the closely related

Table 12
Settling Pond Performance
Stone, Sand and Gravel Operations

	TSS (mg/l)			
Plant	Influent	Effluent	Percent Reduction	Treatment, Chemical
Dimension Stone				
3001	1,808	37	97.95	none
3003	3,406	34	99	$FeCl_3$,sodium bicarbonate
3007	2,178	80	96.3	none
Crushed Stone				
1001	1,054	8	99.24	none
1003	7,680	8	99.92	none
1004	5,710	12	99.79	none
1021	7,206	28	99.61	none
(2 ponds)	772	3	99.61	none
1039	10,013	14	99.86	none
1053	21,760	56	99.74	none
Construction Sand and Gravel				
1017 (D)	5,712	51	99.12	flocculating
1044	5,114	154	96.99	none
1083 (A)	20,660	47	99.77	none
1083 (B)	8,863	32	99.64	none
1129	4,660	44	99.06	none
1247 (D)	93	29	68.82	flocculating agent
1391	12,700	18	99.86	none
Industrial Sand				
1019	2,014	56	97.22	none
1101	427	56	86.88	none
1102	2,160	66	96.94	flocculating

D - Dredge
A - Main Plant
B - Auxiliary Plant

short circuiting. The first can be avoided by constructing a series of ponds as mentioned above. Frequent dredging of the first if needed will reduce the need to dredge the remaining ponds. The solution to the second involves additional pond volume or use of flocculants. The third problem, however, is almost always overlooked. Short circuiting is simply the formation of currents or water channels from pond influent to effluent whereby whole areas of the pond are not utilized. The principles of clarifier construction apply here. The object is to achieve a uniform plug flow from pond influent to effluent. This can be achieved by proper inlet-outlet construction that forces water to be uniformly distributed at those points, such as by use of a weir. Frequent dreding or insertion of baffles will also minimize channelling. The EPA report "Waste Water Treatment Studies in Aggregate and Concrete Production" in detail lists the procedure one should follow in designing and building settling ponds.

FLOCCULATION

Flocculating agents increase the efficiency of settling facilities. They are of two general types: ionic and polymeric. The ionic types such as alum, ferrous sulfate and ferric chloride function by neutralizing the repelling double layer ionic charges around the suspended particles, thereby allowing the particles to attract each other and agglomerate. Polymeric types function by physically trapping the particles.

Flocculating agents are most commonly used after the larger, more readily settled particles (and loads) have been removed by a settling pond, hydrocyclone or other such scalping treatment. Agglomeration, or flocculation, can then be achieved with less reagent and less settling load on the polishing pond or clarifier.

Flocculation agents can be used with minor modifications and additions to existing treatment systems, but the costs for the flocculating chemicals are often significant. Ionic types are used in 10 to 100 mg/l concentrations in the waste water while the higher priced polymeric types are effective in the 2 to 20 mg/l concentrations. Flocculants have been used by several segments within the minerals industry with varying degrees of success.

CLARIFIERS AND THICKENERS

An alternative method of removing suspended solids is the use of clarifiers or thickeners which are essentially tanks with internal baffles, compartments, sweeps and other directing and segregating mechanisms to provide efficient concentration and removal of suspended solids in one effluent stream and clarified liquid in the other.

Clarifiers differ from thickeners primarily in their basic purpose. Clarifiers are used with the main purpose of producing a clear overflow with the solids content of the sludge underflow being of secondary importance. Thickeners, on the other hand, have the basic purpose of producing a high solids underflow with the character of the clarified overflow being of secondary importance. Thickeners are also usually smaller in size but more massively constructed for a given throughput.

Clarifiers and thickeners have a number of distinct advantages over ponds. Less land space is required, since these devices are much more efficient in settling capacity than ponds. Influences of rainfall are much less than for ponds. If desired the clarifiers and thickeners can even be covered. Since the external construction of clarifiers and thickeners consist of concrete or steel tanks, ground seepage and rain water runoff influences do not exist.

On the other hand, clarifiers and thickeners suffer some distinct disadvantages as compared with ponds. They have more mechanical parts and maintenance. They have only limited storage capacity for either clarified water or settled solids. The internal sweeps and agitators in thickeners and clarifiers require more power and energy for operation than ponds.

Clarifiers and thickeners are usually used when sufficient land for ponds is not available or is very expensive. They are found in the phosphate and industrial sand subcategories.

HYDROCYCLONES

While hydrocyclones are widely used in the separation, classification and recovery operations involved in minerals processing, they are used only infrequently for waste water treatment. Even the smallest diameter units available (stream velocity and centrifugal separation forces both increase as the diameter decreases) are ineffective when particle size is less than 25-50 microns. Larger particle sizes are relatively easy to settle by means of small ponds, thickeners or clarifiers or other gravity principle settling devices. It is the smaller suspended particles that are the most difficult to remove and it is these that can not be removed by hydrocyclones but may be handled by ponds or other settling technology. Also hydrocyclones are of doubtful effectiveness when flocculating agents are used to increase settling rates.

Hydrocyclones are used as scalping units to recover small sand or other mineral particles in the 25 to 200 micron range, particularly if the recovered material can be sold as product. In this regard hydrocyclones may be considered as converting part of the waste load to useful product as well as providing the first step of waste water treatment. Where land availability is a problem, a bank of hydrocyclones may serve in place of a primary settling pond. They are used in the phosphate subcategory to dewater sand tailings and in the sand and gravel subcategory to recover sand fines normally wasted.

TUBE AND LAMELLA SETTLERS

Tube and lamella settlers require less land area than clarifiers and thickeners. These compact units, which increase gravity settling efficiency by means of closely packed inclined tubes and plates, can be used for either scalping or waste water polishing operations depending on throughput and design.

CENTRIFUGES

Centrifuges are not used for minerals mining waste water treatment. Present industrial-type centrifuges are relatively expensive and not particularly suited for this purpose. Future use of centrifuges will depend on regulations, land space availability and the development of specialized units suitable for minerals mining operations.

SCREENS

Screens are widely used in minerals mining and processing operations for separations, classifications and beneficiations. They are similar to hydrocyclones in that they are restricted to removing the larger (<50-100 micron) particle size suspended solids of the waste water, which can then often be sold as useful product. Screens are not economically practical for removing the smaller suspended particles.

FILTRATION

Filtration is accomplished by passing the waste water stream through solids-retaining screens, cloths, or particulates such as sand, gravel, coal or diatomaceous earth using gravity, pressure or vacuum as the driving force. Filtration is versatile in that it can be used to remove a wide range of suspended particle sizes. The large volumes of many waste water streams found in minerals mining operations require large filters. The cost of these units and their relative complexity, compared to settling ponds, has restricted their use to a few industry segments committed to complex waste water treatment.

DISSOLVED MATERIAL TREATMENTS

Unlike suspended solids which need to be removed from minerals mining and processing waste waters, dissolved materials are a problem only in scattered instances in the industries covered herein. Treatments for dissolved materials are based on either modifying or removing the undesired materials. Modification techniques include chemical treatments such as neutralization. Acids and alkaline materials are examples of dissolved materials modified in this way. Most removal of dissolved solids is accomplished by chemical precipitation. An example of this is given below, the removal of fluoride by liming:

$$2F^- + Ca(OH)_2 = CaF_2 + 2OH^-$$

With the exception of pH adjustment, chemical treatments are not common in this industrial segment.

NEUTRALIZATION

Some of the waterborne wastes of this study, often including mine drainage water, are either acidic or alkaline. Before disposal to surface water or other medium, excess acidity or alkalinity needs to be controlled to the range of pH 6 to 9. The most common method is to treat acidic streams with alkaline materials such as limestone, lime, soda ash, or sodium hydroxide. Alkaline streams are treated with acids such as sulfuric. Whenever possible, advantage is taken of the availability of acidic waste streams to neutralize basic waste streams and vice versa. Neutralization often produces suspended solids which must be removed prior to waste water disposal.

pH CONTROL

The control of pH may be equivalent to neutralization if the control point is at or close to pH 7. Sometimes chemical addition to waste streams is designed to maintain a pH level on either the acidic or basic side for purposes of controlling solubility. An example of pH control being used for precipitating undesired pollutants are:

(1) $Fe^{+3} + 3OH^- = Fe(OH)_3$

(2) $Mn^{+2} + 2OH^- = Mn(OH)_2$

(3) $Zn^{+2} + 2OH^- = Zn(OH)_2$

(4) $Pb^{+2} + 2(OH)^- = Pb(OH)_2$

(5) $Cu^{+2} + 2OH^- = Cu(OH)_2$.

Oxidation-Reduction Reactions

The modification or destruction of many hazardous wastes is accomplished by chemical oxidation or reduction reactions. Hexavalent chromium is reduced to the less hazardous trivalent form with sulfur dioxide or bisulfites. Sulfides, with large COD values, can be oxidized with air to relatively innocuous sulfates. These examples and many others are basic to the modification of inorganic chemical wastes to make them less troublesome. In general waste materials requiring oxidation-reduction treatments are not encountered in these industries.

Precipitations

The reaction of two soluble chemicals to produce insoluble or precipitated products is the basis for removing many pollutants. The use of this technique varies from lime treatments to precipitate sulfates, fluorides, hydroxides and carbonates to sodium sulfide precipitations of copper, lead and other toxic heavy metals. Precipitation reactions are particularly responsible for heavy suspended solids loads. These suspended solids are removed by settling ponds, clarifiers and thickeners, filters, and centrifuges. The following are examples of precipitation reactions used for waste water treatment:

(1) $SO_4^{=} + Ca(OH)_2 = CaSO_4 + 2OH^-$

(2) $2F^- + Ca(OH)_2 = CaF_2 + 2OH^-$

(3) $Zn^{++} + Na_2CO_3 = ZnCO_3 + 2Na^+$

EXAMPLES OF WASTE WATER TREATMENT

The following text discusses how these technologies are employed by the subcategories covered in this document and the effluent quality.

DIMENSION STONE

The single important water effluent parameter for this industry is suspended solids. In dimension stone processing facilities, water is only occasionally recycled. The following summarizes waste treatment practices.

Stone	Facility	Waste Water Treatment
Mica Schist	5600	settling
Slate	3017	100% recycle
	3018	none
	3053	settling
Dolomitic Limestone	3039	settling
	3040	settling
Limestone	3007	settling
	3008	settling, 100% recycle
	3009	settling
	3010	settling, 100% recycle
Granite	3001	settling
	3029	settling
	3038	flocculants, settling, 100% recycle
	3002	settling
	3003	settling
Marble	3034	settling
	3051	none
	3304	settling
	3305	settling
	3306	settling, polymer, alum

At facility 3038 chemical treatment, solids separation via a raked tank with filtration of tank underflow, plus total recycle of tank overflow is practiced. This is necessary since the facility hydraulic load would otherwise overwhelm the small adjacent river. Furthermore, the facility has a proprietary process for separating silicon carbide particles from other solids for evential reuse. Since granite facilities are the only users of silicon carbide, non-granite processors could not obtain any cost benefits from this SiC recovery practice.

Disposition of quarry and facility waste stone is more a function of state requirements than of any other factor. Thus, waste stone and settling pond solids are conscientiously used to refill and reclaim quarries where the state has strict reclamation laws. Corporate policy regarding disposition of solid wastes is the second most important factor, and type and yield of stone is the least important factor. Thus, where both state and corporate policy are lenient, solid wastes are accumulated in large piles near the quarry (facilities 3017, 3053, and to some extent 3051).

In addition to refilling abandoned quarries, some facilities make real efforts to convert waste stone to usable rubble stone (facilities 3034, 3040), crushed stone (facilities 3051, 3038, 3018), or rip rap (facilities 3051, 3039). Successful efforts to convert low grade stone to low priced products are seen only in the marble, granite, and dolomitic limestone industries.

Pit pumpout does occur as a seasonal factor at some locations, but suspended solids have generally been found to be less than 25 mg/l. The quality of mine water can be attributed more to stone type than to any other factor. For example, granite quarry pumpout at facility 3001 is 25 mg/l TSS. However, limestone, marble, and dolomitic limestone quarry water is generally very clear and much lower in suspended solids.

Several analyses of treated effluents available are as follows:

Facility 3007	7.8 pH 7.1 mg/l TSS (range 0-24.5)
Facility 3304	<10 JTU
Facility 3305	<100 mg/l total solids <5 mg/l TSS <1 BOD
Facility 3306	<1 JTU
Facility 3002	600 mg/l TSS
Facility 3003	34 mg/l TSS
Facility 3001	Water including runoff from 2 quarries 1 mg/l TSS 4 mg/l TSS Finishing Facility-37 mg/l TSS
Facility 5600	Quarry - 7 mg/l TSS

Facility 3051	Quarry - 7 mg/l TSS Facility-1658 mg/l TSS Second Facility-4008 mg/l TSS

CRUSHED STONE (WET PROCESSING)

In all of the facilities contacted, the effluent from the washing operation is sent through a settling pond system prior to discharge. This system generally consists of at least two settling ponds in series designed to reduce the suspended solids in the final discharge. At facility 1439 the suspended solids concentration entering the first settling pond is 7000-8000 mg/l which is reduced to a level of 15-20 mg/l after flowing through the two ponds. Facility 3027 reports its settling pond system reduces the total suspended solid level in the facility washwater by 95 percent.

In some instances (facility 1222), flocculating agents are added to the waste stream from the wash facility prior to entering the first settling pond to expedite the settling of the fine particles. Mechanical equipment may be used in conjunction with a settling pond system in an effort to reduce the amount of solids entering the first pond. At facility 1040, the waste water from the washing operation flows through a dewatering screw which reportedly removes 50 percent of the solid material which represents a salvageable product. The waste water flows from the screw into the first settling pond.

Facility 1039 has an even more effective method for treating waste water from the washing operation. As with facility 1040, the waste water flows into a dewatering screw. Just prior to this step, however, facility 1039 injects a flocculating agent into the waste water which leads to a higher salvage rate.

Of the facilities contacted that wash crushed stone, 33 percent do not discharge their wash water. Many of the remaining facilities recycle a portion of their waste water after treatment. It should be noted that evaporation and percolation have a tendency to reduce the flow rate of the final discharge in many instances. The main concern with the final effluent of a wet crushed stone operation is the level of suspended solids. This may vary depending on the deposit, the degree of crushing, and the treatment methods employed.

The waste water from the wet scrubber in facility 1217 is sent to the first of two settling ponds in series. After flowing through both ponds, the water is recycled back to the scrubber with no discharge. Effluent data from some of the facilities that do discharge wash water after treatment by settling ponds are:

facility	effluent	source
1004	Flow - 8.7 x 10^6 l/day (2.30 mgd) pH - 7.5 Turbidity - 16 FTU	treated discharge composed of wash water (4%) and pit pumpout (96%)
1053	Flow - 1.8 x 10^6 l/day (0.48 mgd) pH - 8.4 Turbidity - 18 FTU	wash water after treatment
1218	Flow - 6.2 x 10^6 l/day (1.64 mgd) TSS - 20 mg/l	wash water after treatment then combined with pit pumpout

Of the facilities contacted the following are practicing total or partial recycle of process generated waste water:

1001
1002
1003
1023
1039
1040
1062
1063
1064
1161
1212
1217
1220
1222
1227
1228
1250
1439
3027
5662
5612
5663
5664

The types of treatment used and the TSS values for raw and treated waste are shown below for a number of facilities.

		TSS	
Facility	Treatment System	Raw Waste	Treated Effluent
1001*	Settling pond	1,054[2]	8[2]
1003	Settling pond (with total recycle)	7,687[2]	7[2]
1004	Settling pond	5,710[2]	12[2]
1021	Settling ponds	7,064, 142[2]	28[2]
		772[2]	3[2]
1023*	Settling pond (with partial recycle)	----	34[1]
1039	Flocculation, dewatering screw and		

	settling pond (with total recycle)	10,013[2]	7[2]
1053	Settling pond	21,760[2]	56[2]
1218	Settling pond (with total recycle)	----	20[1]
1219*	Settling pond (with partial recycle)	----	2[1]
1439	Settling ponds (with total recycle)	7,000-8,000[1]	15-20[1]
5662*	Settling pond (with partial recycle)	----	9[1]
5664*	Settling pond (with partial recycle)	----	40, 42[1]

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[1] Company supplied data

[2] Contractor verification data

* These facilities use a common pond for treating process waste water and mine water.

Many treatment ponds experience ground seepage. Facility 1974 is an example of a facility achieving no discharge because of seepage.

Many of the operators in this subcategory must periodically clean their settling ponds of the fines which have settled out from wash water. A clamshell bucket is often used to accomplish this task. The fines recovered are sometimes in the form of a saleable product (facility 1215) while in most instances these fines are a waste material. In this instance, the material is either stockpiled or used as landfill (facilities 1053 and 1212). The quantity of waste materials entering the pond varies for each operator and the processes involved. Facility 1002 reports that the washwater entering the settling ponds contains 4-5 percent waste fines. The frequency of pond cleaning depends not only on the processes involved but also on the size of the pond. Facility 1217 must clean its settling ponds once per month, the recovered material serving as landfill. The disposal of these fines presents problems for many operators.

CRUSHED STONE (MINE DEWATERING)

Pit pumpout may either be discharged directly with no treatment (facility 1039), discharged following treatment (facilities 1020 and 5640), or discharged with the treated effluent from the washing operation (facility 1001). In the latter case, the quarry water may be combined with the untreated facility effluent and then flow through a settling pond system prior to discharge (facility 5662). The quarry water may instead join the semi-treated effluent as flow to the second of two settling ponds (facility 1213). There are many variations to the handling of pit pumpout.

Mine dewatering data from several facilities of this subcategory are:

facility	TSS mg/l
1001	3
1003	7
1004	12
1020	(1)5, (2)1
1021	1, 1, 6, 1, 12, 2
1022	15
1023	34
1039	7
1040	25
1214	<1,2,3
1215	(1)42, (2)28
1219	2
1224	10-30
3319	1, 1, 1, 1, 2, 4, 5, 5, 5, 9, 11, 15, 17, 21, 35, 38, 38, 55, 64
3320	5, 9, 9, 10, 11, 14, 15, 19, 27, 28, 32, 35, 65, 103, 128
3321	1, 2, 2, 2, 3, 3, 4, 4, 5, 6, 7, 9, 14, 15, 17, 20, 21, 22, 22, 26, 45, 51, 67
5660	14
5661	0
5663	1
5664	42.4

(1) first pit
(2) second pit

CRUSHED STONE MONITORING DATA

NPDES Discharge Monitoring Reports (DMRS) were obtained for more than 65 plants in the crushed stone subcategory. Treatment technologies used at these facilities is unknown. The total number of DMRS was 755, however, only 631 reports had comparable sampling frequencies: one sample in thirty days. The average TSS values for these 631 facilities (some plants have more than one discharge) are given below:

# of DMRS	sample type	avg. mean/avg. max. TSS mg/l
575	quarry dewatering	13.1/24.5
115	commingled	28.0/45.3
9	process water	8.8/29.0

CRUSHED STONE (FLOTATION)

At facility 1975, all waste water is combined and fed to a series of settling lagoons to remove suspended materials. The water is then recycled back to other washing operations with the exception of about 5 percent which is lost by percolation and evaporation from the ponds. This loss is made up by the addition of fresh water.

At facility 3069 a considerable portion of the waste water is also recycled. The individual waste streams are sent to settling tanks for removal of suspended solids. From these, about 70 percent of the process water and all of the cooling and boiler water is recycled. The remainder is released to settling ponds for further removal of suspended solids prior to discharge.

At facility 1021, lagooning is also used for removal of suspended solids. No recycle is practiced.

For facilities 3069 and 1021 the effluents are listed as follows along with corresponding intake water compositions. In the case of facility 1021 the data presented are analytical measurements made by the contractor.

	intake water (3069)	effluent (3069)	intake water (1021)	effluent (1021)
TSS (mg/l)	5	10	3	4
BOD (mg/l)	1.0	<1.0	---	---
COD (mg/l)	1.0	<1.0	0	4
sulfate (mg/l)	3.5	<2.0	13	19
turbidity (FTU)	10	6	4	2
chloride (mg/l)	3.8	4.1	50	20
total solids (mg/l)	32	128	464	154

At Facility 1044, only non-contact cooling water is discharged. The pH of facility 1007 effluent ranges from 6.0-8.0, and the significant parameters are:

Flow, l/kkg of product (gal/ton)	625	(150)
TSS, mg/l	55	
TSS, kg/kkg of product (1 lb/1000 lb)	0.034	

SAND AND GRAVEL

The predominant method of treating process waste water is to remove sand fines and clay impurities by mechanical dewatering devices and settling basins or ponds. Removal of -200 mesh sand and clay fines is much more difficult and requires settling times that are usually not achievable with mechanical equipment. Some facilities use settling aids to hasten the settling process. The best facilities in this subcategory are able to recycle the clarified water back to the process. Water with a total suspended solids content less than 200 mg/l is generally clean enough to reuse in the process. The following tabulates data from facilities which recirculate their process water resulting in no discharge of process waste water:

Facility	Input TSS (mg/l)	Treatment	Output TSS (mg/l)
1055	unknown	spiral classifiers, 4-hectare (10-acre) settling basin	25
1235	unknown	mechanical thickeners, settling ponds	54
1391	4,550	mechanical thickeners, cyclones, 2-hectare (5-acre) settling basin	32
1555	15,000	cyclones, 14-hectare (35-acre) settling basin	35
3049	5,000	cyclones, vacuum disc filter, 2-hectare (5-acre) settling pond with polymer floc	30
5617	unknown	dewatering screws, settling ponds	unknown
5631	unknown	dewatering screws, 10-hectare (25-acre) settling pond	unknown
5674	unknown	dewatering screws, 0.8-hectare (2-acre) settling pond	unknown

Facilities 1012 and 5666 are hydraulic dredging facilities. Slurry from these facilities is sent to a settling basin to remove waste fines and clays. The decant from the settling basin is returned to the wet pit to maintain a constant water level for the dredge resulting in no discharge of process water to navigable waters. Facilities 3339 and 3340 likewise achieve no discharge.

Lack of land to a major extent will impact the degree to which a facility is able to treat its process waste water. Many operations are able to use worked-out sand and gravel pits as settling basins. Some have available land for impoundment construction. The following lists the suspended solids concentration of treated waste water effluents from facilities discharging:

Facility	Treatment	TSS, mg/l
1006	dewatering screw, settling ponds	55
1044	dewatering screw, settling pond	154
1056	settling ponds	25
1083	dewatering screw, settling ponds	47
1129	dewatering screw, settling ponds	44
5630	dewatering screw, settling ponds	2, 3, 4

Facility 1981, using heavy-media separation, recovers the magnetite and/or ferrosilicon pulp, magnetically separates the media from the tailings, and returns the media to the process. Separation tailings from the magnetic separator are discharged to settling basins and mixed with process water.

Pit pumpout and non-contact cooling water are usually discharged without treatment. Facilities 1006 and 5630 discharge pit pumpout water through the same settling ponds which handle process water. Facility 1044 discharges non-contact cooling water through the same settling ponds used for treating process water. Dust suppression water is adsorbed on the product and evaporated.

Half the facilities visited are presently recirculating their process water resulting in no discharge. Those facilities recirculating all process generated waste water include:

1007
1013
1014
1048
1055
1056
1057
1058
1059
1084
1200
1201
1202
1203
1204
1205
1206
1207
1208
1230
1233
1234
1236
1250
1391
1555
1629
3049
5622
5631
5656
5674
1235
5617
3341

The following facilities achieve no discharge to navigable waters by percolation:

1231 1232 5666 5681

The following facilities previously mentioned as recycling all process generated waste waters declared that significant perculation occurs in their ponds:

1057 1058 1233 1234 5656

Facilities 1005, 1012, 5670 dredge closed ponds on their property and discharge all process waste waters back to the pond being dredged. Only very large rainfalls would cause a discharge from these ponds to navigable waters. Facility 3342 discharges pit water (never exceeding 21 mg/l TSS) in order to maintain the pond level.

The rest discharge process water. Characteristics of some discharges are:

Facility	Flow l/kkg of product (gal/ton)	TSS kg/kkg of product (lb/1000 lb)
1006	2500 (600)	0.14
1044	1670 (400)	0.26
1056	1750 (420)	0.04
1083	1040 (250)	0.05
1129	1150 (275)	0.05
5630	1170 (290)	0.006

Solid wastes (fines and oversize) are disposed of in nearby pits or worked-out areas or sold. Clay fines which normally are not removed by mechanical equipment settle out and are routinely cleaned out of the settling pond. Facilities 1391 and 1629 remove clay fines from the primary settling pond, allow them to drain to approximately 20 percent moisture content, truck the wastes to a landfill site, and spread them out to enhance drying.

SAND AND GRAVEL (DREDGING-ON LAND PROCESSING)

At dredge 1009, there is no treatment of the sand slurry discharged to the river. Removal of waste fines at land facilities with spiral classifiers, cyclones, mechanical thickeners, or rake classifiers and settling basins, is the method of process waste water treatment. These are similar to methods used in the wet processing subcategory. Facilities 1046, 1048, 1051 and 1052, by utilizing mechanical devices and settling basins, recirculate all process water thereby achieving no discharge. The following is a list of treatment methods, raw waste loads, and treated waste water suspended solids for these operations:

Facility	Raw Waste Load, TSS (mg/l)	Treatment	Treated Recycle Water, TSS (mg/l)
1046	8,500	dewatering screw, cyclone, drag classifier, settling basin	275
1048	10,000	dewatering screw, cyclones, settling basins	50
1051	9,000	dewatering screw, drag classifier, settling basin	300
1052	7,500	dewatering screw, drag classifier, settling basin with flocculants	200

Availability of land for settling basins influences the method of process water treatment. Many operations use worked-out sand and gravel pits as settling basins (Facility 1048) or have land available for impoundment. Facility 1010 is not able to recirculate under current conditions due to lack of space for settling basins. Land availability is not a problem at facilities 1011 and 1009. Sand fines (+200 mesh) are removed with mechanical devices and conveyed to disposal areas. Clay fines and that portion of the silica fines smaller than 200 mesh, which settle out in a settling basin, are periodically dredged and stockpiled. Facility 1051 spends approximately 120 days a year dredging waste fines out the primary settling pond. These fines are hauled to a landfill area. Non-contact cooling water is typically discharged into the same settling basins used for treating process water. Dust suppression water is adsorbed onto the product and evaporates. Effluent parameters at facilities 1010 and 1009 are:

Facility	TSS mg/l	TSS, kg/kkg of product (lb/1000 lb)
1010	16,000	22
1009	50	0.10

INDUSTRIAL SAND (DRY)

Scrubber water at facility 1107 is treated in a settling pond where suspended solids are settled and the clarified decant is returned to the scrubber, resulting in no discharge. Facility 1108 discharges wet scrubber water without any treatment at 166,000 l/day (43,000 gpd) and 33,000 mg/l TSS. Solid waste (oversize and sand fines) at all of the facilities is landfilled.

INDUSTRIAL SAND (WET)

Under normal conditions facilities 1019, 1989, and 3066 are able to recirculate all process water by using clarifiers and pond the sludge. During periods of heavy rainfall, area runoff into the containment ponds cause a temporary discharge. Facility 1102 discharges process water, including wet scrubber water, after treatment in settling ponds. The treatment methods used by the facilities are shown as follows:

Facility	Treatment
1019	thickener, clarifier, settling pond, recycle
1102	cyclone, thickener and flocculant, settling ponds
1989	settling pond and recycle
3066	settling pond and recycle

INDUSTRIAL SAND (FLOTATION)

At the acid flotation facilities, facilities 1101, 1019, 1980, and 1103, all process wash and flotation waste waters are fed to settling lagoons in which muds and other suspended materials are settled out. The water is then recycled to the process.

Facilities 1101 and 1980 are presently producing products of a specific grade which allows them to totally recycle all their process water. In two other facilities, facilities 1019 and 1103, all facility waste waters leave the operations either as part of a wet sludge which is land disposed or through percolation from the settling ponds. There is no point source discharge from any of the acid flotation operations.

At the alkaline flotation facility 5691, the washwaters are combined and fed to a series of settling lagoons to remove suspended materials and then partially recycled. Alum is used as a flocculating agent to assist in settling of suspended materials, and the pH is adjusted prior to either recirculation or discharge.

At facility 5980, the only facility found that uses HF flotation, all waste waters are combined and fed to a thickener to remove suspended materials. The overflow containing 93.2 percent of the water is recycled to the process. The underflow containing less than 7 percent of the water is fed to a settling lagoon for removal of suspended solids prior to discharge. The pH is also adjusted prior to discharge. Fluoride ion concentration in the settled effluent ranges from 1.5 to 5.0 mg/l. The composition of the intake and final effluent waters for the alkaline flotation facility 5691, and the HF flotation facility 5980 are presented as follows.

Pollutants (mg/l)	Facility 5691		Facility 5980	
	Intake	Effluent	Intake	Effluent
pH	7.8	5.0	7.6	7.0-7.8
TDS	209	192	---	---
TSS	5	4	10	5,47
Sulfate	9	38	285	27-330
Oil and Grease	<1.0	<1.0	---	---
Iron	0.1	0.06	---	---
Nitrate	---	---	23	0-9
Chloride	---	---	62	57-76
Fluoride	---	---	0.8	1.8,6.6
Phenols	Not detectable			

INDUSTRIAL SAND (ACID LEACHING)

Process water at facility 3215 is treated by neutralization with slaked limestone and lagooning to settle part of the iron. The existing system of settling ponds is an extensive one; this treatment system contains approximately ten acres of ponds.

The effluent from the treatment system is combined with the effluent from the company's construction sand plant. The combined effluents are discharged to surface waters. The composition of the combined effluent is given below:

	kg/kkg (lb/ton) of product
pH (units)	
max.	7.2
min.	6.4
TSS	
average	1.01 (2.02)
Iron	

average	0.065 (0.13)

GYPSUM

Mine or quarry pumpout is generally discharged without treatment. Most facilities discharge non-contact cooling water without treatment. Effluent data for some facilities discharging mine or quarry water are given as follows:

facility	flow, 10^6 l/day (mgd)	TSS, mg/l	pH
1041	4.4 (1.17)	6	7.7
1042	6.4 (1.70)	4	7.8
1110	.19 (0.05)	60	7.8
1112	5.1 (1.35)	14	8.1
1997	0.68 (0.18)	5	7.9
1999	6.5 (1.71)	24	7.4

Non-contact cooling water discharge from these facilities is given below:

facility	flow, l/kkg of product (gal/ton)	TSS mg/l	pH
1041	none	--	--
1042	246 (59)	not known	not known
1112	none	--	--
1997	250 (60)	6	7.9
1999	4.5 (1)	130	5

Land plaster dust collected in cyclones is either recycled to the process or hauled away and landfilled.

All process water used for heavy media separation at facility 1100 and the one other facility in this subcategory is re-circulated through settling basins, an underground mine settling sump, and returned to the separation circuit, resulting in no discharge of process waste water. In the recycle circuit, the HMS media (magnetite/ferrous silica) is reclaimed and is reused in the separation process.

Part of the waste rock from the HMS is sold as road aggregate, with the remainder being landfilled in old worked-out sections of the quarry. Waste fines at facility 1100 settle out in the primary settling basin and must be periodically dredged. This waste is hauled to the quarry and deposited.

BITUMINOUS LIMESTONE

No water is used in these operations hence there is no effluent.

OIL IMPREGNATED DIATOMITE

All scrubber water at facility 5510 is completely recycled; hence there is no process waste water discharge.

GILSONITE

The compositions of the intake water, the discharged facility process water and the mine pumpout water are listed below. There is a considerable concentration of suspended solids in the mine pumpout water. These discharges are currently being eliminated. The process and mine pumpout waters currently discharged at facility 5511 will soon be employed on site for other purposes.

	Concentration (mg/l)		
	intake	effluent	mine pumpout
Suspended solids	33	17	3375
BOD	35	43	12
pH	7.7	8.2	7.9 - 8.1
TDS	401	2949	620
Turbidity	--	--	70 JTU
Arsenic	--	--	0.01
Barium	--	--	<0.01
Cadmium	--	<0.001	0.004
Chloride	--	0.15	8.8
Sulfate	--	363	195

ASBESTOS

Facility 3052 treats the quarry pumpout discharge with sulfuric acid (approximately 0.02 mg/l of effluent) to lower the pH of the highly alkaline ground water that collects in the quarry. The following tabulates the analytical data for this discharge:

flow, l/day (mgd)	545,000-3,270,000 (0.144-0.864)
TSS, mg/l	2.0
Fe, mg/l	0.15
pH	8.4-8.7
asbestos (fibers/liter)	$1.0 - 1.8 \times 10^6$

At all facilities, both at the mine and facility site, there exists the potential of rainwater runoff contamination from asbestos waste tailings. Facility 1061 has constructed diversion ditches, berms, and check dams to divert and hold area runoff from the waste tailing pile. Due to soil conditions, water that collects in the check dams eventually percolates into the soil thereby resulting in no discharge to surface waters.

At the wet processing facility the process water discharge is treated in settling/percolation ponds. Suspended asbestos fibers settle out in the primary settling pond prior to decanting the clarified effluent to the secondary settling/percolation pond. Facility 1060 does not discharge to surface waters. Non-contact cooling water is not treated prior to discharge. Runoff from asbestos tailings at the facility and the quarry is controlled with diversion ditches, berms, and check dams. All facility drainage is diverted to the settling/percolation ponds. Data on the waste stream to the percolation pond includes the following:

	Intake Well Water	Discharge to Percolation Pond
flow, l/kkg feed(gal/ton)	unknown	856 (205)
total solids, mg/l	313	1,160
pH	7.5	7.8
magnesium, mg/l	14	48
sodium, mg/l	44	345
chloride, mg/l	19	104
nickel, mg/l	0.02	0.1

Asbestos fiber tailings are stockpiled near the facility where the water is drained into the settling/percolation ponds. After some drying, the tailings are transported and landfilled near the facility in dry arroyos or canyons. Check dams are constructed at the lower end of these filled-in areas.

The primary settling pond must be periodically dredged to remove suspended solids (primarily asbestos fibers). This is done with a power shovel, and the wastes are piled along-side the pond, allowed to dry, and landfilled.

WOLLASTONITE

Non-contact cooling water is discharged with no treatment to a nearby river. There is no process waste water.

PERLITE

There is no water used.

PUMICE

At all facilities except facility 1705, there is no waste water to be treated. At facility 1705, the scrubber water is discharged to a settling pond for removal of suspended materials prior to final discharge. Facility 1705 operates on an intermittent basis, and no information is available on the composition of its discharge. This facility produces less than 0.1 percent of U.S. pumice.

VERMICULITE

Both vermiculite operations have no discharge of waste waters. At facility 5506, the waste stream is pumped to a series of three settling ponds in which the solids are impounded, the water is clarified using aluminum sulfate as a flocculant, and the clear water is recycled to the process facility. The only water escape from this operation is due to evaporation and seepage from the pond into ground water. The overburden and sidewall waste is returned to the mine upon reclamation.

At facility 5507, the waste streams are pumped to a tailings pond for settling of solids from which the clear water underflows by seepage to a reservoir for process water to the process facility. Local lumbering operations are capable of drastically altering water runoff in the watersheds around the mine. This requires by-pass streams around the ponding system.

MICA AND SERICITE (WET GRINDING)

At facility 2055, the raw waste stream is collected in surge tanks and about 20 percent of the decanted water is recycled to the process. The remainder is pumped to a nearby facility for treatment. The treatment consists of adding polymer, clarification and filtration. The filter cake is stockpiled and the filtrate discharged. At facility 2059, the waste stream flows to settling tanks. The underflow from the settling tanks is sent back to the process for mica recovery. The overflow goes into a 0.8 hectare (2 acre) pond for settling. The decanted water from this pond is recycled to the process. However, during heavy rainfall, the settling pond overflows.

MICA (WET BENEFICIATION)

In facilities 2050, 2051, 2053, and 2058 the wastes are treated by settling in ponds, and the supernatant from the last pond is recycled to the facility. The sizes of the ponds used at each facility are given as follows.

Facility	hectares	acres
2050	7.3	18
2051	3.2	8
2053	0.8, 1.6, 2.8	2, 4, 7
2058	8.1	20

During normal operations there is no discharge from ponds 2050 and 2051. However, these ponds discharge during exceptionally heavy rainfalls (4" rain/24 hours). The only discharge at facility 2058 is the drainage from the sand stockpiles which flows into a 0.4 hectare (1-acre) pond and discharges.

At facility 2054 waste water is treated in a 1.2 hectare (3-acre) pond. This facility has suspended its operation since June, 1974, due to necessary repairs to the pond, and plans to convert the water flow system of this operation to a closed circuit "no discharge" process by the addition of thickening and filtration equipment.

At facilities 2052 and 2057 the waste water is treated in a series of ponds and the overflow from the last pond is treated by lime for pH adjustment prior to discharge. Facility 2052 has three ponds of 1.2, 1.6, and 3.6 hectares (3, 4, and 9 acres, respectively) in size. In addition to mica, these two facilities produce clay for use by ceramic industries. According to responsible company officials, these two facilities cannot operate on a total water recycle basis. The amine reagent used in flotation circuits is detrimental to the clay products as it affects their viscosity and plasticity. The significant constituents in the effluent from these facilities are given below:

facility	2052	2054	2057
pH before lime treatment	4.2	---	4.3
pH after lime treatment	6.5	6 - 9	6.5
TSS, mg/l	20	400	<15
TSS, kg/kkg	1.5		<1.3
settleable solids, ml/liter	<0.1	<0.1	<0.1

BARITE (WET)

The waste water streams are combined and sent to settling ponds and the reclaimed water from the ponds is recycled to the washing facilities. At facilities 2012 and 2046, the overflow from the settling pond percolates through gravel piles amassed around the settling pond, and enters clarification ponds. The supernatant water from the clarification pond is then recycled to the facilities for reuse. Also, in these facilities (2012 and 2046), there are several small ponds created around the main impoundment area to catch any accidental overflow from the clarification ponds. Besides ponding, facilities 2015 and 2016 also use coagulation and flocculation to treat their process waste water. A summary of the treatment systems for the barite facilities in this subcategory follows:

Facility	Discharge	Source	Treatment
2011	Intermittent*	Mill tailings, runoff	Pond recycle, 18 ha (45 ac)
2012	Intermittent* from clear water pond	Well water	Pond 8 ha (20 ac)
	None from tailings pond	Mill tailings	Pond, 36 ha (90 ac) Clarification Pond, recycle
2013	None	Mill tailings	Pond, recycle
2015	Intermittent*	Mill tailings, runoff	Pond, coagulation Flocculation, recycle
2016	Intermittent*	Mill tailings, runoff	Pond, coagulation Flocculation, recycle
2017	Intermittent*	Mill tailings, runoff	Pond, recycle
2018	Intermittent*	Mill tailings, runoff	Pond, recycle Pond 24 ha (60 ac)

2020	Intermittent* from clear water pond	Well water	
	None from settling pond	Mill tailings	Pond, 2 ha (6 ac)
2046	Intermittent* from clear pond	Well water	Pond, 12 ha (30 ac) clarification
	None from tailings pond	Mill tailings	Pond, recycle
2112	None	Slime Pond	Pond recycle

*Indicates overflow due to heavy rainfall.

In normal circumstances, there is no effluent discharge from any of these facilities. During heavy rains six facilities (2011, 2015, 2016, 2017, 2018 and 2020) have an overflow from the impoundment area. Facilities 2012 and 2046 have no overflow from their tailings impoundment area. However, during heavy rainfall, they do have overflow from clear water ponds. Due to its geographical location, facility 2013 has no pond overflow. The amounts of these intermittent discharges are not known. Data concerning tailings pond effluent after heavy rainfall was obtained from one facility. The significant constituents in this effluent are reported as follows:

Facility	2011 Daily Avg.	- Max.
pH	6.0	- 8.0
TSS, mg/l	15	32
Total barium, mg/l	0.1	- 0.5
Iron, mg/l	0.04	- 0.09
Lead, mg/l	0.03	- 0.10

BARITE (FLOTATION)

Wastewater is treated by clarification and either recycled or discharged. A summary of the treatment systems is given as follows:

Facility	Discharge	Source	Treatment
2010	Intermittent [1]	Mill tailings	Pond, recycle
	Intermittent	Runoff, spills, washdown water	Pond
2014	None	Mill tailings	Pond, evaporation and seepage
	None	Washdown water	Pond, evaporation and seepage
2019	Intermittent [2]	Mill tailings	Pond

[1] Indicates overflow due to heavy rainfall
[2] Overflow by facility to maintain pond level

Facility 2010 has two ponds with a total capacity of 16 hectares (40 acres) to handle the process waste water. The flotation tailings are pumped into one of the ponds and the clear water is pumped to the other pond. The mill tailings water is in closed circuit, with occasional overflow from the tailings pond. This overflow depends upon the amount of surface water runoff from rainfall and the amount of evaporation from this pond. The overflow varies from 0 to 760 l/min (0 to 200 gpm). At times, there is no overflow from this pond for a year or more. The clear water pond catches the surface runoff water, spills from the thickener, water from use of hoses, clear water used in the laboratory, etc. This pond has also an intermittent discharge varying from 0 to 380 l/min (0-100 gpm). The significant constituents in these effluent streams are as follows:

Waste Material	Tailings Pond Daily Average Max. Conc. (mg/l)	Amount kg/day	(lb/day)	Clear Water Pond Daily Average Max. Conc. (mg/l)
TSS	3-5	1.8	(3.5)	3-6
TDS	800-1271	467	(934)	1000-1815
Ammonia	<0.1-0.1	<0.5	(1)	5-35
Cadmium	0.004-0.008	<0.5	(1)	--
Chromium	0.200-0.400	<0.5	(1)	0.100-0.120
Iron, total	0.030-0.060	<0.5	(1)	0.030-0.070
Lead, total	0.020-0.080	<0.5	(1)	0.040-0.090
Manganese, total	0.002-0.008	<0.5	(1)	0.004-0.008
Nickel, total	0.030-0.070	<0.5	(1)	0.030-0.070
Zinc, total	0.005-0.010	<0.5	(1)	0.030-0.090

At facility 2014, there are no effluent discharges from the property. The mill tailings and the spent brine from the water softening system are pumped into the tailings settling pond and the washdown of the floors is pumped to a separate pond. These ponds eventually dry by evaporation and seepage. This facility has no problem in terms of pond overflow due to its geographical location.

At facility 2019, process waste water is collected into a large pipe which crosses under the nearby river into a 40 hectare (100 acre) pond. The pond water pH is maintained at about 7.2 by application of lime. An overflow is necessary from this pond to maintain a constant pond elevation. The discharge from this pond is intermittent. Of the 4,731,000 l/day (1.25 mgd) input to the pond, there is an estimated 3,785,000 l/day (1.0 mgd) percolation through the pond berm. The pond berm is built primarily of river bottom sands. On a regular discharge basis (9 hours a day and 4 1/2 days per week operation), the effluent discharge from this facility would be 946,000 l/day (250,000 gal/day). This pond is seven years old and has an estimated life cycle of eighteen years. When overflow to the river is desired, lime and ferric chloride are used to decrease suspended solids. It has been reported that the average TSS concentration in this effluent is 250 mg/l.

BARITE (MINE DEWATERING)

There is one underground mine in this category at facility 2010. The other mining operations are in dry open pits. The underground mine workings intercept numerous ground water sources. The water from this mine is directed through ditches and culverts to sumps in the mine. The sumps serve as sedimentation vessels and suction for centrifugal pumps which discharge this water to the upper level sump. This mine water is neutralized with lime (CaO) by a continuously monitored automated system for pH adjustment and sent to a pond for gravity settling prior to discharge into a nearby creek. The discharge from this mine is estimated to be 897,000 l/day (237,000 gal/day).

The raw waste from the mine has a pH of about 3.0. The pH is raised to 6-9 by addition of lime and then pumped into a pond for gravity settling. There are currently two ponds, and a third pond is under construction to treat the mine discharge. Presently one of these ponds is in use and the other one is being excavated and cleaned so that it will be ready for use when the first pond is filled.

The significant constituents in this effluent are reported to be as follows:

Parameter	Facility Data	New Pond Design	Verification Sampling
pH			2.6
Acidity			404
Hardness			3920
TDS			4348
TSS	23	25	1167
$SO_4^=$			1515
Fe, total	2.6	0.5	225
Fe, dissolved			177
Al	0.6	0.1	13.8
Pb	0.06	0.1	>0.2
Mn	1.3	0.5	156
Ni	0.05	0.05	1.52
Zn	0.01	0.1	2.1

The facility stated that the verification data reflect new acid seepage from adjoining property. The column "new pond design "represents the company's design criteria for building the third pond.

FLUORSPAR (HMS)

At four facilities (2004, 2005, 2006 and 2008) process water from the thickener is pumped to either a holding pond or reservoir, and then back to the facility on a total recycle basis. At facility 2009, there are four ponds to treat the HMS tailings. Three of these ponds are always in use. The idle pond is allowed to dry and is then harvested for settled fluorspar fines. There is no discharge from this facility. At facility 2007 the HMS tailings enter a 1.8 hectare (4.5 acre) pond which has eight days of retention capacity. The water from this pond is then discharged. The significant constituents in the effluent from facility 2007 is given as follows:

Waste Components	mg/l	kg/kkg of product (lb/1000 lb)
Fluoride	3.0	0.04
TSS	10.0	0.13
Lead	0.015	0.0002
Zinc	0.09	0.0012
pH	7.8	

FLUORSPAR (FLOTATION)

The waste water of the facilities in this subcategory is treated in settling and clarification ponds. At facility 2000, the mill tailings are pumped into a 7 hectare (17 acre) settling pond for gravity settling. The overflow from the settling pond flows into three successive clarification ponds of 2.8, 1.6, and 2.4 hectares (7, 4, and 6 acres, respectively). The effluent of the third clarification pond is discharged. Settling in the third clarification pond is hindered by the presence of carp and shad which stir up the sediments. Experiments are in progress using a flocculant in the influent line of the second clarification pond to reduce the total suspended solids in the effluent. These clarification ponds are situated below the flood stage level of the nearby river, and during flood seasons, the water from the river backs into the ponds. Some mixing does occur but when flood waters recede, but it is claimed that most of the sludge remains in the ponds.

At facility 2001, the tailings from the fluorspar rougher flotation cells, are pumped into a settling pond from which the overflow is discharged. Facility 2001 has a new 4 hectare (10 acre) clarification pond with a capacity of approximately 106 million liters (28 million gallons). The effluent from the first settling pond will be pumped to the new clarification pond. A flocculant will be added to the influent of the new pond in quantities sufficient to settle the suspended solids to meet the state specifications (TSS 15 mg/l). A portion of the water from the clarification pond (approximately 20 percent) will be recycled to the processing facility and the remainder which cannot be recycled will be discharged.

Total recycle operation has been attempted on an experimental basis by one of these operations for a period of eight months, without success. The failure of this system has been attributed to the complexity of chemical buildups due to the numerous reagents used in the various flotation circuits.

The non-contact cooling water and the boiler blowdowns are discharged at facility 2001 without treatment. Facility 2000 includes these wastes in the process waste water treatment system. Facility 2003 mines an ore which is different from the ores processed in the other two facilities. This facility produces only fluorspar. The tailings from the mill go to two settling ponds in series. The overflow from the second settling pond is sent to the heavy media facility, and there is no discharge. A new pond is being constructed at facility 2003.

Effluents reported by facilities 2000 and 2001 for their current operation and anticipated performance are:

	concentration (mg/l)			
	2000		2001	
	Current operation	Anticipated	Current operation	Anticipated
pH	7.2	no change	8.2	no change
TSS	500	30-60	1,800	15-20
Fluoride	5.1	5.1	9.8	9.8

	kg/kkg of product (lb/1000 lb)			
	2000		2001	
	Current operation	Anticipated	Current operation	Anticipated
TSS	4.8	0.29-0.57	34.4	0.29-0.38
Fluoride	0.05	0.05	0.19	0.19

Additional sampling are by concentration (mg/l):

	2000	2001
pH	7.7	8.2
Alkalinity	359	340
Hardness	222	325
TSS	316	235
TDS	1056	1702
F	0.742	10
Fe (total)	5	2.9
Cd	0.13	0.02
Cr	0.11	0.05
Cu	2.39	0.35
Pb	0.86	0.20
Mn	0.43	0.17
Zn	<0.01	1.13

FLUORSPAR (MINE DEWATERING)

Presently at only three mines the effluent stream is discharged without any treatment (2085, 2091 and 2092). Only effluent from mine 2091 passes through a very small pond, 0.1 hectare (1/4 acre), prior to being discharged into a creek. Table 13 summarizes the effluent quality of several mine dewatering operations. Hydrogen sulfide concentrations up to 0.37 mg/l have been detected in the effluent of mine 2085. It has been reported that the H_2S content in the effluent has been steadily decreasing since an H_2S pocket was encountered.

TABLE 13

FLUORSPAR MINE DEWATERING DATA

mg/1	2080	2081	2082	2083	2085 mine	2085 settling pond	2086	2088	2089	2090	2091	2092 mine	2092 settling pond	2093
pH	8.1		7.1	7.6	7.6	7.4		7.7	8.1	7.7	7.2	7.9	8.0	
Alkalinity				224	276	216	245		864			210	197	
Hardness				336	1600	1600			221			235	222	
Cl				35	185	162			48			23	17	
TSS	38	10	8	2-12	15	29	12	20	122-135	4-69	10	53	20	17
TDS	469	697	400	478	3417	1753		1078	583	536		379	364	
$SO_4^=$		35		107	480	575			61	56		38	32	
F	1.4	2.4	1.4	1.3		2.75	1.7	2.3	1.4	2.3	3.2		1.6	
Fe		1.0		0.05	0.66	0.26	.05		2.0	0.05	.05	1.33	0.50	0.9
Pb	.03	0.1	.02	< 0.2	< 0.2	< 0.2	.03	.03	< 0.2	< 0.2	0.9	< 0.2	< 0.2	0.075
Mn		0.16		0.05	0.05	0.62			0.11	0.01		0.18	0.18	0.1
Zn	0.7	0.03	.08	0.76	< 0.01		0.34	0.54	0.06	0.5	0.2	0.17	0.08	0.235

SALINES (BRINE LAKES)

As the evaporation-crystallization process involves only recovery of salts from natural saline brines, with the addition of only process water, the only wastes are depleted brines and end liquors which are returned to the salt body without treatment.

BORAX

Present treatment consists of percolation-proof evaporation ponds with no discharge.

POTASH

All waste streams from the sylvinite facilities are disposed of in evaporation ponds with no discharge. At the langbeinite facilities 20-30 percent of the cooling water is evaporated. All the process waste water from the langbeinite purification facilities are fed to evaporation ponds with no discharge. All known deposits of sylvinite and langbeinite ore in the U.S. are located in arid regions.

TRONA

Process waste waters go to tailings separation ponds to settle out the rapidly settling suspended materials and then to the final disposal ponds which serve as evaporation ponds. Where process water discharge takes place (at present only facility 5933), the overflow is from these latter ponds. Facility 5933 has plans to eliminate this discharge. The ground water and runoff waters are also led to collection ponds where settling and large amounts of evaporation take place. The excess of these flows at the 5962 and 5976 facilities is discharged.

Evaporation of the saline waste waters from these facilities takes place principally in the summer months since the ponds freeze in the winter. The net evaporation averaged over the year apparently requires an acre of pond surface for each 2,000 to 4,000 gal/day (equivalent to 19,000 to 37,000 l/day per hectare) based on present performance.

There is no discharge from facility 5999. Facility 5976 only mines ore and discharges only mine water. The facility 5962 discharge is only ground and runoff waters. The waste constituents after treatment of the discharge at 5933 were at the time of permit application:

	mg/l	kg/day	(lb/day)
total solids	9,000	860	(1,900)
dissolved solids	8,300	793	(1,750)
suspended solids	700	67	(150)

SODIUM SULFATE

There are no discharges due to total evaporation at the arid locations involved.

ROCK SALT

Generally there is no treatment of the miscellaneous saline waste water associated with the mining, crushing and sizing of rock salt. Some of the facilities have settling ponds. Facility 4028 is unique in that the mine shaft passes through an impure brine aquifer and entraps hydrogen sulfide gas. The seepage from this brine stream around the shaft is contained by entrapment rings. The solution is filtered, chemically treated and re-injected into a well to the aquifer.

The effluents from these facilities consist primarily of waste water from the dust collectors, miscellaneous washdown of operating areas, and mine seepage. The compositions of some of the facility effluents expressed in mg/l are as follows:

	Volume		TDS	TSS	pH
Facility	l/day	gal/day	mg/l	mg/l	
4013	4,090,000	1,080,000	4,660	trace*	--
4026	150,000	40,000	30,900	72	7.5
4027	500,000	132,000	--	150	6.5
4033	76,000	20,200	30,200	trace**	--
4034 (001)	306,000	81,000	53,000 - 112,000	470 -	8.5-9.0
(002b)	522,000	138,000	319,000 - 323,000	1,870 4,750	7.6

* due to dilution
** runoff only, remainder of waste re-injected to well.

The suspended solids content in the process water discharges from facilities 4013, 4026, and 4027 range up to 0.02 kg/kkg of product. At least one of these facilities discharges an average of as little as 0.002 kg/kkg of product.

PHOSPHATE

Some facilities use well water for pump seal water (>2000 gpm) claiming that this is necessary in order to protect the seals. Others, facility 4015 for example, use recycled slime pond water with no problems. Some facilities also claim that well water is necessary for air scrubbers on dryers in order to prevent nozzle plugging and utilize the cooler temperature of the well water to increase scrubber efficiency. Other facilities also recycle this with no apparent difficulty. Facility 4018 recycles this water through a small pond that treats no other wastes.

The treatment of the process waste streams consists of gravity settling through an extensive use of ponds. The slimes which are common to all phosphate ore beneficiation processes, although differing in characteristics, are the major waste problem with respect to disposition. The slimes at 3-5 percent solids either flow by gravity via open ditch with necessary lift stations or are pumped directly to the settling ponds. The pond overflow is one of the primary sources of the recycle process water. Those facilities that include flotation discharge sand tailings at 20-30 percent solids to a mined out area. Settling occurs rapidly with a part or all of the water returned to recycle and the solids used in land reclamation. The pond sizes are quite large, 160 hectares (400 acres) being typical. A single process facility will have several such ponds created from mined areas. Because the slimes have such a great water content, they will occupy more space than the ore. Hence dams need to be built in order to obtain more volume. Because of past slime pond dam breaks, the construction of these dams is rigorously overseen in the state of Florida. The treatment of the mine pit seepage and dust scrubber slurries are handled similarly to the other waste streams. Facility 4003 discharges some of the mine pumpout.

Effluents are intermittently or continuously discharged from one or more settling areas by all of the beneficiation facilities. Volumes of effluents are related to: (1) % recycle; (2) frequency of rainfall; (3) surface runoff; and, (4) available settling pond acreage. The pH of the effluents from these facilities range from 6.2 to 9.1 with over 70 percent of the averages between 7 and 8.

Sufficient data was available from the Florida phosphate and processing facilities to use statistical methods. For a given plant normal and logarithmic normal distributions were tested on the individual daily values for TSS and the monthly averages for TSS. It was found that a three parameter logarithmic normal distribution best fit the data. Figure 57 plots log TSS (mg/l) versus probability for one facility. At higher values of Tau, the TSS values fit a straight line determined by a least squares program very well.

The following data summarize the results of the statistical analyses:

PHOSPHATE EFFLUENT QUALITY
TSS, mg/l

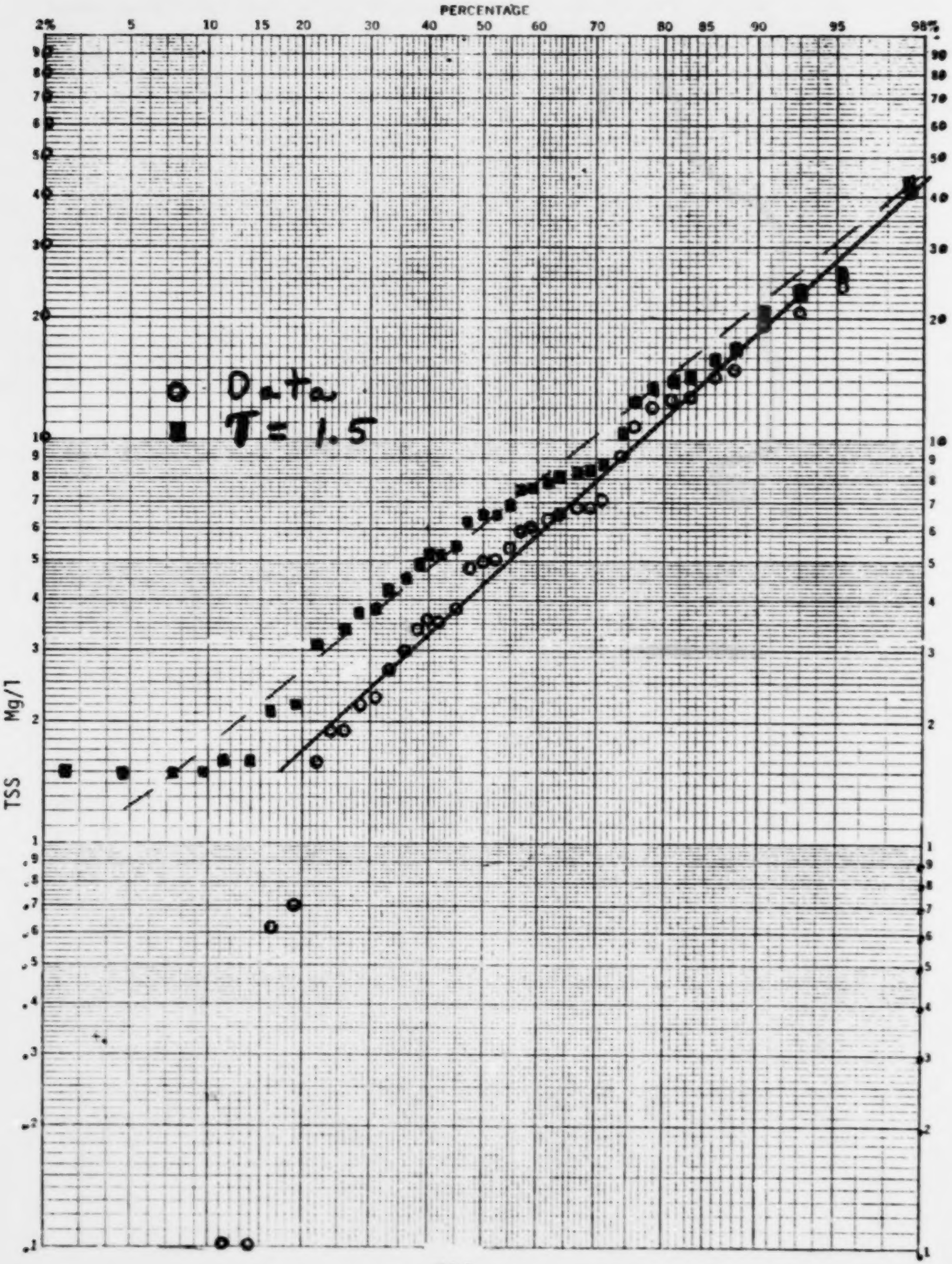
	Long Term Average		Monthly 99 Percentile	Observed Maximum Monthly Average		Daily 99 Percen-tile		Observed Daily Maximum	
	*	**	*	*	**	*	**	*	**
4002	9.2	-	38.6	26	-	220	-	64	-
4004A(1)	9.7	10.8	17.4	14	27	50.7	50.4	50	44
4004A(2)	11.3	8.2	-	-	16	47.3	39.8	30	32
4004B(1)	13.5	8.3	70.3	53	8	68.5	12.8	103	12.0
4004B(2)	3.5	3.1	7.3	6	5	16.1	10.7	12	7
4004B(3)	2.5	2.3	8.1	5	4	8.5	7.9	10	7
4005A(1)	18.1	21.7	35.5	29	33	59.8	51.3	75	49
4005A(2)	-	19	-	-	26	-	48.4	-	47
4005B(1)	18.7	13.1	28.7	25	27	56.4	71.5	67	62
4005B(2)	16.0	16.9	25.7	22	27	38	41.6	35	41
4005C(1)	13.2	17.0	29.4	23	29	44.6	43.0	47	47
4005C(2)	15.0	19.1	-	-	26	75.9	46.1	55	37
4005C(3)	28.2	14.6	-	-	23	116.1	74.4	105	70
4015(1)	15.8	18.3	20.7	18	24	39	52.4	36	55
4015(2)	46.5	34.0	190.8	109	91	303	221	181	182
4015(3)	14.9	7.9	-	-	18	24.0	32.8	20	24
4016	7.4	9.2	17.5	13	16	20.2	47.9	17	46
4018	158	26.4	798	453	137	1334	-	1072	1961
4019A	7.0	-	17.3	13	-	43.1	-	41	-
4019B	5.6	5.2	24.5	18	9	33.3	18.6	-	15
4019C	6.3	4.9	36.2	17	9	54.0	20.7	43	15
4020A	2.8	3.7	6.8	5	37	21.1	68.0	14	143
4020B	5.5	7.5	7.0	6	14	12.3	21.3	12	28

*1974-1975 Data
**1975-1976 Data

Some caution must be exercised when reviewing the data. For instance some of the data noted are weekly composites and it can be expected that the daily variability will be somewhat higher. Some of the analyses, on the other hand, were

FIGURE 57

Normal Distribution of Log TSS for a Phosphate Slime Pond Discharge



performed on less than 12 data points. This was the case for some monthly data.

In other cases poor sampling techniques were employed by the facilities, and some data were not analyzed because of facility admissions of improper sampling. In other cases high TSS values resulted from erosion of the earthen discharge ditches or the inclusion of untreated facility and road surface runoff.

In addition to TSS, the slimes from beneficiation and facility effluents contain radium 226 resulting from the presence of uranium in the ores. Typical radium 226 concentrations in slimes and effluents are presented in the following table:

Radium 226 Concentrations (pCi/liter)

	Slime Discharge			Effluent Discharge		
Facility	dissolved	undis-solved	g/liter	discharge point	dissolved	undis-solved
			*82			
4005	0.82	10.2	0.48	A-4*	0.66	0.26
				K-4*	0.52	0.28
				K-8*	0.68	0.28
			*86			
4015	4.8	1074	14.8	002*	0.02	0.56
				003*	0.34	1.1
4016	2.0	97.6	3.2	001*	2.2	0.70
4017	0.60	37.7	3.85	001	0.24	0.74

*4 hour composite sample

The concentration of total radium 226 appears to be directly related to the concentration of TSS.

The treatment of the process waste stream for the Western operations consists typically of flocculation and gravity settling with some facilities having a thickening stage prior to ponding. The slimes consist primarily of fine clays and sands. At facility 4022, the flotation tailings (primarily sands) are combined with the slimes with treatment common to the other operations. The waste slurries vary in percent solids from 5 to 15. Generally a flocculating agent is added before pumping to a thickener or directly to a settling pond where the solids settle out rapidly.

Of the six facilities surveyed, only facility 4022 currently has a discharge. Some part of the overflow and seepage from the settling pond flows into a small retention basin which occasionally discharges. This facility received a discharge permit stipulating no discharge and intends to have complete recycle and/or impoundment of process water.

SULFUR (FRASCH - ANHYDRITE)

There are no process waste waters emanating from these facilities. The only waste from these facilities is sludge which originates from the water purification operation, and it is sent to a thickener where as much water as possible is reclaimed for recycling back to the system. At facility 2020 approximately 90 percent of the thickener sludge is used as an additive to the mud that is injected into the ore body in order to improve the thermal and hydrologic efficiency of the mine. The remaining 10 percent is pumped into a settling pond for evaporation. At facility 2095, the entire thickener sludge is used as drilling mud.

SULFUR (FRASCH - SALT DOME)

The major waste from the sulfur mines is the bleedwater from the formation. Due to the nature of the mining operation, it is not possible to significantly reduce the quantity of the bleedwater produced. Large aeration ponds are considered to be the best technology available for treating the water from the bleed wells. However, due to the scarcity of land space for ponds near some of these mines, each facility uses a unique treating system to reduce the hydrogen sulfide and suspended solid concentrations in the bleedwater effluent streams.

There are four waste streams at facility 2021. Outfalls #1 (power facility effluent), #2 (sludge from the domestic water treating facility), and #5 (water from sealing wells, miscellaneous sanitary waste and drips and drains) are disposed of in a seawater bay leading into the Gulf without any treatment. Outfall #3 (bleedwater) is first flashed into a large open top tank which causes reduction in hydrogen sulfide concentrations. After a short residence in the tank, this effluent is mixed with seawater to effect further oxidation of the hydrogen sulfides to sulfates and to dilute it before discharge. A flash stripping and oxidation system was chosen for this facility primarily because of a new procedure of up-flank bleeding which precluded the continued use of the existing treatment reservoir.

The location of mine 2022, some 9.6 to 11.2 km (6 to 7 miles) offshore in the Gulf, does not lend itself to the conventional aeration reservoir. Mechanical aeration systems are considered undesirable by this company due to the large quantities of gaseous hydrogen sulfide that would be released to the atmosphere and come in contact with personnel on the platform. Some quantities of dissolved hydrogen sulfide are swept out of the solution through gaseous evolution of carbon dioxide and methane present in the formation water. Additionally, oxidation of sulfides occurs through the reaction with the dissolved oxygen in the seawater by using a diffuser system. The results of water sampling, since the mine began operations, have shown an absence of sulfides within 150 m (500 ft) of the discharge points. Because conventional treatment systems (ponds) cannot be used and because relocation is impossible, situations such as this will be regulated in a separate subcategory.

Presently, there is only one major waste stream at facility 2023. However, there are 6 other discharge points from this facility primarily for rainwater runoffs. This mine has three pumping stations in the field for rain water runoffs which are newly designated discharge points. In addition, there are 3 discharge points installed to cover rainwater runoffs and the drips and drains from the levee system around the power facility. This levee system has been built to improve the housekeeping in the power facility area. The bleedwater from the mine is aerated in one of three small reservoirs, located in the field area, prior to pumping to the main treatment reservoir which is about 10 hectares (25 acres) in size. Here the water is sprayed to reduce hydrogen sulfide concentrations. It is then impounded for 3-4 days where further aeration occurs. Finally, it is mixed with pumped-in seawater at a ratio of 20 to 1 in a 1830 meter (6000-foot), man-made canal to oxidize any remaining sulfides to sulfates prior to discharge. Power facility wastes are also piped into the canal where temperatures are equilibrated and solids are settled. Oxidation is effecting sulfide removal in this ditch rather than just dilution as evidenced by the avearage reduction of sulfide from 107 mg/l to less than 0.1 mg/l before and after mixing with the seawater. A spray system was chosen for aeration in this facility due to the lack of suitable land space for the construction of a large conventional reservoir.

Four discharge streams emanate from facility 2024. Discharges #1 and #3, the power facility discharges and mining water from sealing wells, respectively, discharge into a river without treatment. Discharge #2, the bleedwater, flows by gravity through a ditch into a 50 hectare (125 acre) reservoir where oxidation of hydrogen sulfide is accomplished. The effluent residence time in this reservoir is about 15 to 18 days. The treated bleedwater flows into a swift flowing tributary of a river just before it enters tidal waters. All sewage effluents entering into discharge #4, which is primarily rain runoff, are treated through a septic tank system prior to discharge.

At mine 2025 the bleedwater flows to a small settling basin from where it is routed through a mixing zone. Sulfurous acid and deposition inhibitor are added to the bleedwater in this mixing zone and then the waste water is routed to packed towers for hydrogen sulfide removal. In the packed towers, the bleedwater flows counter current to cooled boiler flue gas. The treated bleedwater is next aerated and sent to a 10 hectare (25 acre) settling basin. The overflow from the settling basin flows through two 10-12 hectare (25 to 30 acre) clarification ponds, prior to discharge into the tidal section of a river through a 35 km (22 mile) long disposal canal. The effluents from the water softening and treating operations are discharged into an earthen pond to settle the solids and the sludge. The supernatant water from this pond is discharged into a river. The solids are mixed with some clay and used as substitute drilling mud. Rainfall runoffs, boiler blowdown and other facility area wastes are discharged without treatment. The sanitary waste is treated in a septic tank system and then discharged into oxidation ponds. The overflows from these ponds are discharged into a river.

In mine 2026, the bleedwater is treated in a series of three ponds for settling and oxidation. Pond #1 is about 14 hectares (35 acres) and ponds #2 and #3 are about 52 hectares (130 acres) each on size. The overflow from pond #1 flows through a 3.2 km (2 mile) ditch into pond #2. The overflow from the third pond is discharged into a river. Part of the rainfall runoff, a small part of the boiler blowdown (the continuous blowdown is returned to the mine water system), zeolite softener regeneration water, pump gland water, and washwater are sent into a nearby lake without treatment. The blowdown from the hot process softening system and clarifier system is discharged to pits where the excess supernatant is discharged with the remaining rainfall runoffs into the creek. The settled solids are used as drilling mud. The sanitary waste of this mine is treated in a septic tank system and reused in the mine water system.

At mine 2027 the bleedwater treatment process used consists of contacting the waste water from the bleedwells with sulfurous acid with provisions for adequate mixing followed with sufficient retention time. Sulfurous acid is made both by burning liquid sulfur or from hydrogen sulfide originating from the bleedwater. In this process, the soluble sulfides in the bleedwater are converted to elemental sulfur and oxidized sulfur products in a series of reaction vessels. The excess acid is next neutralized with lime and the insoluble sulfur is removed by sedimentation. The effluent thus treated passes through five basins in series having a total retention capacity of about one day. The overflow from the last basin is discharged into a salt water canal which flows into the tidal section of a river. The waste stream from the water clarification operation is discharged into an earthen pond to settle the solids and the sludge. The supernatant water from this pond is mixed with boiler blowdown waste and other waste streams prior to discharge into the salt water canal. Rainfall runoffs are sent into the canal without any treatment. The sanitary waste of this mine is treated in a septic tank system and then discharged into a disposal field.

In mine 2028, the water from the bleedwells is sent into two separate tanks from where it flows through 24 km (15 miles) of underground piping into a ditch about 5 km (3 miles) in length. From there it flows into a 325 hectare (800 acres) pond for oxidation and settling. Treated effluent from this pond is discharged 60 days per year into a ditch. This is because the canal water, while subject to tidal influence, is selectively used for irrigation supply water. The waste stream from the water clarifier and zeolite softening operation is discharged into an earthen pond to settle the solids and the sludge. The supernatant water from this pond is intermittently pumped out into a creek. The solids are mixed with some clay and used as drilling mud. Boiler blowdown water, facility area wastes and rainfall runoffs are sent into a nearby creek. The sanitary waste of this mine is treated in a septic tank system and then discharged in a disposal field.

The rainfall runoffs, boiler blowdowns, waste resulting from the water softening and treating operations, facility area wastes are sent into receiving waterways without any treatment. Therefore, the composition of these streams are as given in the raw waste load section. Table 14 compares the discharges from these facilities. Alternate forms of sulfur treatment are discussed in the following paragraphs.

Oxidation-Reduction Reactions

The modification or destruction of many hazardous wastes is accomplished by chemical oxidation or reduction reactions. Hexavalent chromium is reduced to the less hazardous trivalent form with sulfur dioxide or bisulfites. Sulfides can be oxidized with air to relatively innocuous sulfates. The oxidation reactions for a number of sulfur compounds pertinent to the sulfur industry are discussed below.

TABLE 14

SULFUR FACILITIES
COMPARISON OF DISCHARGES

Plant	2021	2023	2024	2025	2026	2027	2026	2029	2097
Age	14	41	21	45	26	22	17	28	6
Location	La *	La *	La	Tx	Tx	Tx	Tx	Tx	Tx
Total Discharge, 10^6 1/day	74	428	19	38	17	23	11.5	8.7	11.5
Total Discharge 10^3 1/kkg	180	260	6.9	12.1	20	20.5	21.5	11.8	22.1
Bleedwater discharge, 10^6 1/day	4.6	27	19	38	17	23	11.5	8.7	11.5
Bleedwater discharge, 10^3 1/kkg	11.2	16.4	6.9	12.1	20	20.5	21.5	11.8	22.1
Pollutants (in total discharge)									
TSS, mg/1	57	33	95	30	20	5	40	50	30
TSS, kg/kkg	10.3	8.6	0.7	0.4	0.4	0.1	0.9	0.6	0.7
Sulfide, mg/ 1	16	0.4	51	nil	nil	nil	nil	not de-	2
Sulfide, kg/kkg	2.9	0.1	0.4	nil	nil	nil	nil	tected	0.04
TSS (seawater contribution omitted) kg/kkg	4.8	0.3	0.7	0.4	0.4	0.1	0.9	0.6	0.7

* Bayou

Inorganic Sulfur Compounds

Inorganic sulfur compounds range from the very harmful hydrogen sulfide to the relatively innocuous sulfate salts such as sodium sulfate. Intermediate oxidation products include sulfides, thiosulfates, hydrosulfites, and sulfites. Oxidation of sulfur compounds is accomplished with air, hydrogen peroxide, chlorine, amoung others.

(1) Sulfides

Sulfides are readily oxidizable with air to thiosulfate. Thiosulfates are less harmful than sulfides (of the order of 1000 to 1).

$$2HS^- + 2O_2 = S_2O_3^{=} + H_2O$$

The reaction goes to 90-95 percent completion.

(2) Thiosulfates

Thiosulfates are difficult to oxidize further with air (21). They can be oxidized to sulfates with powerful oxidizing agents such as chlorine or peroxides. However, the Frasch sulfur industry has experienced oxidation of sulfides with air to elemental sulfur and oxidation of thiosulfides to sulfates.

(3) Hydrosulfites

Hydrosulfites can also be oxidized by such oxidizing agents and perhaps with catalyzed air oxidation.

(4) Sulfites

Sulfites are readily oxidized with air to sulfates at a 90-99 percent completion level. Chlorine and peroxides are also effective.

Salt dome sulfur producers have large quantities of bleedwater to treat and dispose of. This presents two problems: removal of sulfides and disposal of the remaining brine. Since there is currently no practical or economical means of removing the salt from the brine, it must be disposed of either in brackish or salt water, or impounded and discharged intermittently during specified times.

Removal of sulfides prior to discharge of the brine is also a major treatment problem. There are two types of bleedwater treatment facilities found in this industry for removal of sulfides. Examples of each are given in Figure 58.

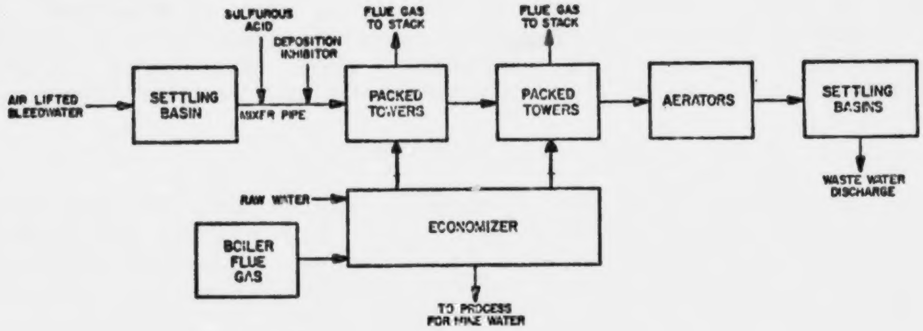
In treatment type 1 the bleedwater is air lifted to a small settling basin and then sent to a mixing zone where sulfurous acid and deposition inhibitor are added. The bleedwater is then sent to packed towers for removal of hydrogen sulfide. In the packed towers the bleedwater flows countercurrent to cooled boiler flue gas. The treated bleedwater is then aerated and sent to a series of settling and clarification ponds prior to discharge. This method is effective for removal of sulfides in the bleedwater.

In treatment type 2 the bleedwater is mixed with sulfurous acid which is generated by burning liquid sulfur or from hydrogen sulfide originating from the bleedwater. In this process the soluble sulfides in the bleedwater are converted to elemental sulfur and oxidized sulfur products in a series of reaction vessels. Excess acid is then neutralized with lime. The insoluble sulfur is removed by sedimentation, and the treated effluent is then sent to a series of basins prior to discharge. This method is very effective for removal of sulfides.

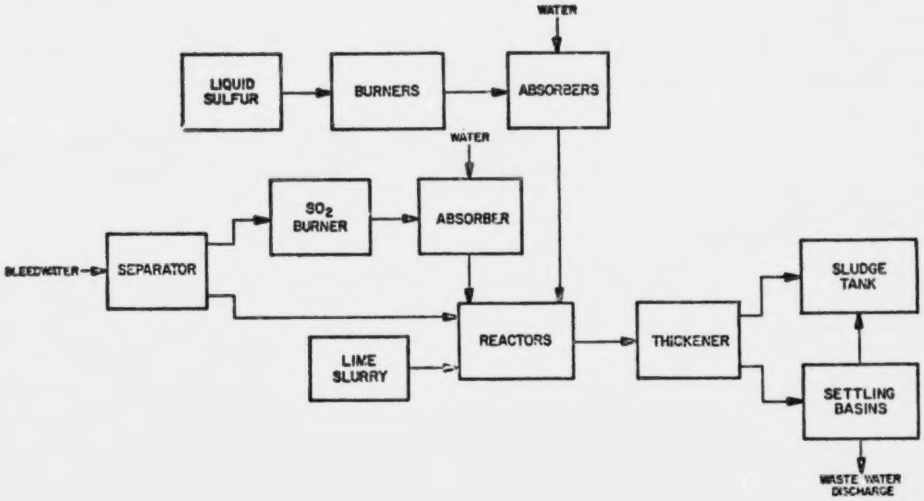
SULFUR (FRASCH - OFFSHORE)

At the one off-shore salt dome sulfur facility currently operating, the bleedwater is discharged without treatment through a diffuser system. The treatment technologies used by on-shore salt dome facilities, ponding and bleedwater treatment facilities are not considered feasible here due to non-availability of land and space restrictions on a platform.

FIGURE 58


SULFUROUS ACID
DEPOSITION INHIBITOR
FLUE GAS TO STACK
FLUE GAS TO STACK
AIR LIFTED BLEEDWATER
SETTLING BASIN
MIXER PIPE
PACKED TOWERS
PACKED TOWERS
AERATORS
SETTLING BASINS
WASTE WATER DISCHARGE
RAW WATER
BOILER FLUE GAS
ECONOMIZER
TO PROCESS FOR MINE WATER

BLEEDWATER TREATING PLANT
TYPE I


WATER
LIQUID SULFUR
BURNERS
ABSORBERS
WATER
SO_2 BURNER
ABSORBER
BLEEDWATER
SEPARATOR
REACTORS
LIME SLURRY
THICKENER
SLUDGE TANK
SETTLING BASINS
WASTE WATER DISCHARGE

BLEEDWATER TREATING PLANT
TYPE 2

PIGMENTS

In the wet processing of iron oxide pigments, water overflow from the rake thickener drains to a large settling pond. It is then recycled to the process with no further treatment. At facility 3022 the waste water is discharged to a 41 hectare (100 acres) settling pond which is also used for effluent from a barite operation. The discharge from the large pond is mainly attributable to the barite operations.

LITHIUM

The treatment of the process waste stream consists of flocculation and gravity settling. The slimes and flotation tailings are primarily alkali aluminum silicates and quartz. A flocculating agent is added and the slurry is pumped to settling ponds, and the major part of the overflow is returned to the facility for re-use. The mine water which is pumped intermittently is both discharged and recycled to the process water circuit. An additional waste stream which is unique to facility 4009 arises from the scrubbing circuit of the low-iron process which removes certain impurities from the spodumene concentrate product. This stream is currently being impounded for future treatment prior to being discharged.

For facility 4009 the point of measurement of the discharge encompasses significant flow from two streams which pass through the property and serve as an intake water source to the facility. The significant dilution by stream water makes it impossible to assess the effluent quality directly. Effluent data are as follows:

	Facility 4001		Facility 4009	
	Mine	Mill	Mine	Mill
Flow l/day			0.57	7.9
mgd			0.15	2.088
pH		6.1-7.9		7.0-7.5
TSS, mg/l	14	41	256	3 3 6 6 6 7 10 13 14 14 15 18 25

Facility 4001 is currently constructing an impoundment and will recycle all process waste water. Facility 4009 is essentially achieving no discharge. Discharge does occur as seepage from the tailings dam and as overflow from the tailings pond during heavy rainfall.

The mine water at mine 4001 was observed by the project officer to be very muddy, possibly requiring use of flocculants.

BENTONITE

There is no discharge of any waste water from bentonite operations. The solid overburden removed to uncover the bentonite deposit is returned to mined-out pits for land disposal and eventual land reclamation. Dust collected from processing operations is either returned to storage bins as product or it is land-dumped. Mine dewatering was not found.

FIRE CLAY

There is no discharge of process waste waters. Mine pumpout is discharged either after settling or with no treatment. The effluent quality of mine pumpout at a few mines are as follows:

Mine	Treatment	pH	TSS mg/l	Total Fe mg/l
3083	Pond	7.25	3	
3084	Lime & Pond	6.5	26.4,62	
3087	lime, combined with other waste streams	4.0	45	
3300	None	6.0-6.9	4	
3301	None	6.9	2	
3302	None	8.3	30	
3303	None	7.0	1	
3307	None	9.2	5	
3308	Pond	5.0	16	20
3309	Pond	4.2		80
3310	None	3.0	16	
3332	None	--	30	--
3333	None	--	10	--
3334	None	--	45	--

3335	None	--	27,144	--
3336	None	--	37	--
3337	None	--	15	--
3338	None	2.6-3.0	253-392	530-1900

ATTAPULGITE

Bearing cooling water at facility 3060 is discharged with no treatment while water used in pugging and kiln cooling is evaporated in the process. Dusts and fines are generated from drying and screening operations at facility 3060. This slurried waste is sent to worked-out pits which serve as settling ponds. In the last year the ponds have been enlarged and modified to allow for complete recycle of this waste water. The ponds have not yet totally filled however, and the company anticipates no problems. There is no discharge at this time of process water. At facility 3058 waste is generated from screening operations as fines which until presently were slurried and pumped to a settling pond. With the installation of new reconstituting equipment these fines are recycled and there is no discharge of process water. The settling pond, however, is maintained in event of breakdown or the excessive generation of fines. Facility 3088 also has installed recycle ponds recently and anticipates no trouble. Facility 3089 uses a dry micro-pulsair system for air pollution control, therefore there is no discharge of process water. According to the company they are within state air pollution requirements.

Mine pumpout at facilities 3060 and 3058 is discharged without treatment. Facility 3089 uses two settling ponds in series to treat mine pumpout, however they do not attempt to treat wet weather mine pumpout. Data of the mine dewatering discharges follow.

Mine	pH	TSS, mg/l
3058	6.8	17
3060	7.5	19

MONTMORILLONITE

Facilities 3059 and 3073 recycle essentially 100 percent of the scrubber water, while facility 3072 recycles only about 70 percent. Scrubber water must be kept neutral because sulfate values in the clay become concentrated, making the water acidic and corrosive. Facilities 3059 and 3073 use ammonia to neutralize recycle scrubber water, forming ammonium sulfate. Facility 3072 uses lime ($Ca(OH)_2$), which precipitates as calcium sulfate in the settling pond. To keep the scrubber recycle system working, some water containing a build-up of calcium sulfate is discharged to a nearby creek. However, facility 3072 intends to recycle all scrubber water by mid-1975. Mine pumpout can present a greater problem for montmorillonite producers than for attapulgite producers, due to the very slow settling rate of some of the suspended clay. Accumulated rain and ground water is pumped to abandoned pits for settling to the extent possible and is then discharged. At facility 3073 the pit water is used as makeup for the scrubber water.

Data on mine dewatering follows.

Mine	pH	TSS,mg/l				
3059	4.5-5.5	200-400				
3323	3.8-4.4	2	4.33	6.3	6.3	
		6.7	8	8	9	9.5
		10.3	12.33	16	18	
		24	33	42	52	
		258				
3324	6-9	25.7	26	30	37	
		53	137	436		
3325	7-8	0.67	1.67	2	3	
		4.33	5.5	8	11	
		12	18	21.3	60	

The high value of 258 mg/l TSS at mine 3323 occurred during a 6.6 cm (2.6 in) rainfall. However, the mine was not being dewatered.

In June 1975, the representatives of a flocculant manufacturer conducted a study of the mine dewatering quality at plant 3059. By use of a flocculant, TSS was reduced from 285 to 15 mg/l and turbidity from 580 to 11 JTU. The flocculant manufacturer's representatives were confident that a full scale system would also produce significant reduction of TSS. Flocculation tests were also conducted at mine 3324. With a cationic polyelectrolyte 50 mg/l TSS was achieved. With supplemental alum 10 mg/l TSS was achieved.

KAOLIN (DRY)

The solid waste generated is land-disposed on-site. There is no process effluent discharged.

KAOLIN (WET)

The facilities treat the process waste water ponds with lime to adjust pH and remove excess zinc which is used as a bleaching agent. This treatment effects a 99.8% removal of zinc, 99.9% removal of suspended solids, and 80% removal of dissolved solids. These facilities are considering the use of sodium hydrosulfite as bleach to eliminate the zinc waste. Facilities with large ponds and a high freeboard have the capability of discontinuing discharge for one or more days to allow unusually high turbidities to decrease before resuming a discharge.

Solid wastes generated in kaolin mining and wet processing are land-disposed with overburden being returned to mined-out pits, and dust, fines, and other solids to settling ponds.

Waste waters are in all cases sent to ponds where the solids settle out and the water is discharged after lime treatment. A statistical analysis was performed on five Georgia kaolin treatment systems. Based on a 99 percent confidence level of the best fitting distribution (normal and logarithmic normal) the following turbidities were achieved.

Facility	Turbidity, JTU or NTU		
	long term average	daily maximum	monthly average maximum
3024	26.4	48.2	<43
3025	24.5	83	62.5
3314	58.2	202	
3315(1)	32.9	140	113.7
3315(2)	32.7	76.7	

Long term TSS data was not available. What TSS values were available were correlated with the corresponding turbidity values as follows:

Facility	TSS, mg/l	
	50 JTU(NTU)	100 JTU(NTU)
3024	45	90
3025	35	70
3315	50	100

Two interesting items were noted in additional data collected at the request of EPA at facility 3315. Approximately one-half of the total suspended solids were of a volatile nature confirming the company's concern that aquatic growth in part was contributing to the suspended solids. This is expected, since organic reagents are used in kaolin processing and the treatment ponds are situated in swampy areas having an abundance of plant growth. The second point is that only about one-half of the turbidity was removed after waste water samples were filtered in the determination of TSS. This indicated that the kaolin and possibly the volatile solids are sub-micron in size and are not necessarily measured by TSS alone.

KAOLIN (MINE DEWATERING)

Open pit mining of kaolin does not utilize any water. However, when rainwater and ground water accumulate in the pits it must be pumped out and discharged. Usually this pumpout is discharged without treatment, but, in at least one case, pH adjustment is necessary prior to discharge.

The following mine drainage concentrations were measured.

Mine	TSS, mg/l	JTU
3074	10	
3080	10	
3081	10	
3311	22	
3312	7.4	
3313	41	
3316	95.2*	44.6*
3317		232*
3318		79.5*

*daily maximum achieved in 99 percent of samples

Mine 3316, 3317 and 3318 blunge the ore at the mine site and add a dispersant such as sodium tripolyphosphate to the slurry to facilitate pumping the ore to the process plant. It is this dispersant that causes the relatively high values.

BALL CLAY

Mine pumpout is discharged either after settling in a pond or sump or without any treatment. Data are as follows:

Mine	TSS, mg/l	
3326	0	23143
3327	48	
3328	0	312
3329	0	
3330	53	
3331	15	200
5684	146	

The extreme variability of the effluent quality is due to the presence of colloidal clays, as observed by the project officer after a substantial rainfall.

Scrubber water at these facilities is sent to settling ponds. In addition, facilities 5684 and 5689 treat the scrubber water with a flocculating agent which improves settling of suspended solids in the pond. Facility 5689 has three ponds of a total of 1.0 hectare (2.5 acres) area.

The amounts of process wastes discharged by these facilities are calculated to be:

facility	discharge, l/kkg of product (gal/ton)	TSS, kg/kkg of product (lb/1000 lb)	TSS mg/l	TDS mg/l
5684	88 (21)	0.0004	4	240
5685	1,080 (260)	0.43	400	1047
			2970	236
			82	511
			1016	433
			1054	
5689	834 (1,030)	0.17	10046	3216
			49	153
			107	164
			4	273

There are two significant types of operations in ball clay manufacture insofar as water use is concerned: those having wet scrubbers, which have a waste water discharge, and those without wet scrubbers, which have no process waste water. There is a discrepancy in discharge flow rates since not all the production lines in each facility have wet scrubbers. Baghouses are also employed by this industry.

FELDSPAR (FLOTATION)

Treatment at three facilities (3054, 3065, 3068) consists of pumping combined facility effluents into clarifiers, with polymer added to aid in flocculation. Both polymer and lime are added at one facility (3065). At the other two facilities, (3026, 3067) there are two settling ponds in series, with one facility adding alum (3026).

Measurements by EPA's contractor on the performance of the treatment system at facility 3026, consisting of two ponds in series and alum treatment, showed the following reductions in concentration (mg/l):

	TSS	Fluoride
waste water into system	3,790	14
discharge from system	21	1.3

The process water effluents after treatment at these five facilities have the following quality characteristics:

facility	pH	TSS mg/l	Fluoride mg/l
3026	6.5-6.8	21	8, 1.3
3054	6.8	45	15
3065	10.8*	349	23
3067	7.5-8.0	35	34
3068	7-8	40-150	32

Facility 3065 adds lime to the treatment, which accounts for the higher than average pH.

The average amounts of the suspended solids and fluoride pollutants present in these waste effluent streams calculated from the above values are given in the following table together with the relative effluent flows.

facility	ore processed basis flow, l/kkg (gal/ton)	TSS, kg/kkg (lb/1000 lb)	fluoride, kg/kkg (lb/1000 lb)
3026	14,600 (3,500)	0.31	0.12
3054	12,500 (3,000)	0.56	0.18
3065	11,000 (2,640)	1.1	0.25
3067	6,500 (1,560)	0.23	0.22
3068	18,600 (4,460)	0.7-2.8	0.6

The higher than average suspended solids content of the effluents from 3065 and 3068 is caused by a froth carrying mica through the thickerners to the discharges. Facility 3026 uses alum to coagulate suspended solids, which may be the cause of the reduction in fluoride. Alum has been found in municipal water treatment studies to reduce fluoride by binding it into the sediment. The effectiveness of the treatment at 3026 to reduce suspended solids is comparable to that at facilities 3054 and 3067.

The treatment at facility 3054 results in little or no reduction of fluoride, but good reduction of suspended solids. Nothing known about this treatment system would lead to an expectation of fluoride reduction.

The treatment at facility 3067 apparently accomplishes no reduction of fluoride, but its suspended solids discharge is significantly lower than average in both amount and concentration.

Solid wastes are transported back to the mines as reclaiming fill, although these wastes are sometimes allowed to accumulate at the facility for long periods before removal.

FELDSPAR (NON-FLOTATION)

Waste water is spilled on the ground (Facility 3032) or is evaporated during crushing and milling operations (Facility 3064). There is no waste water treatment at either facility, since there is no discharge.

KYANITE

Process water used in the several beneficiation steps is sent to settling ponds from which clear water is recycled to the process. There is total recycle of the process water with no loss through pond seepage.

There is normally no discharge of process water from facility 3015. The only time pond overflow has occurred was after an unusually heavy rainfall. Facility 3028 has occasional pond overflow, usually occurring in October and November.

The solid waste generated in kyanite processing is land-disposed after removal from the settling ponds. An analysis of pond water at facility 3015 showed low values for BOD_5 (2 mg/l) and oil and grease (4 mg/l). Total suspended solids were 11 mg/l and total metals 3.9 mg/l, with iron being the principal metal.

MAGNESITE

The waste stream at the one magnesite facility is the underflow of the tailings thickener which contains large quantities of solid wastes. Make-up water is added to transport these wastes to the tailings pond. The estimated area of this pond is 15 hectares (37 acres). The estimated evaporation at this area is 21 cm/yr (54 in/yr) and the annual rainfall is 2.4 cm/yr (6 in/yr). The waste water is lost about 40 percent by evaporation and about 60 percent by percolation. No discharge from the mill is visible in any of the small washes in the vicinity of the tailings pond, and also, no green vegetative patches, that would indicate the presence of near surface run-offs, were visible. The tailings pond is located at the upper end of an alluvial fan. This material is both coarse and angular and has a rapid percolation rate. This could account for the lack of run-off.

SHALE AND COMMON CLAY

There is no waste water treatment necessary for shale and common clay mining and processing since there is no process water used. When there is rainfall or ground water accumulation, this water is generally pumped out and discharged to abandoned pits or streams.

APLITE

Facility 3020 discharges effluent arising from wet scrubber operations to a creek after allowing settling of suspended solids in a series of ponds. Aplite clays represent a settling problem in that a portion of the clays settles out rapidly but another portion stays in suspension for a long time, imparting a milky appearance to the effluent. The occasional mine pumpout due to rainfall is discharged without treatment.

Facility 3016 recycles water from the settling ponds to the process with only infrequent discharge to a nearby river when pond levels become excessive (every 2 to 3 years). This discharge is state regulated only on suspended solids at 649 mg/l average, and 1000 mg/l for any one day. Actual settling pond water analyses have not been made. When this occurs, the pond is treated with alum to lower suspended solids levels in the discharge. Likewise, when suspended solids levels are excessive for recycle purposes, the pond is also treated with alum.

The solid wastes generated in these processes are land-disposed, either in ponds or as land-fill, with iron bearing sands being sold as beach sand.

TALC MINERALS
(LOG WASHING AND WET SCREENING)

The waste streams emanating from the washing operations are sent to settling ponds. The ponds are dried by evaporation and seepage. In facility 2035, when the ponds are filled with solids, they are harvested for reprocessing into saleable products. There is no discharge from these properties.

TALC (MINE DEWATERING)

Underground mine workings intercept numerous ground water sources. The water from each underground mine is directed through ditches and culverts to sumps at each mine level. The sumps serve as sedimentation basins and seals for centrifugal pumps which discharge this water to upper level sumps or to the surface. In some mines, a small portion of the pump discharge is diverted for use as drill wash water and pump seal water; the remainder is discharged into a receiving waterway. The disposition and quantities of mine discharges are given as follows:

Mine	pH	TSS mg/l	l/day (gal/day)	Disposition
2036	7.5-8.3	4, 9	545,000 (144,000)	Pumped to a swamp
2037	7.8	3	878,000 (232,000)	Pumped to a swamp
2038	8.1	4	1,920,000 (507,000)	Pumped to a swamp
2039	7.0-7.8	1, 3	1,900,000 (507,000)	Open ditch
2040	7.2-8.5	15	1,100,000 (300,000)	Settling basin than to a brook
2041	8.7	28	49,200 (13,000)	Settling basin then to a brook
2042	7.8	9	496,000 (131,000)	Settling basin then to a brook
2043	7.6	5	76,000 (20,000)	Settling basin then to a river

TALC (FLOTATION AND HMS)

At facility 2031, the mill tailings are pumped into one of the three available settling ponds. The overflow from these settling ponds enters by gravity into a common clarification pond. There is a discharge from this clarification pond. The tailings remain in the settling ponds and are dried by natural evaporation and seepage.

At facility 2032, the mill tailings are pumped uphill through 3000 feet of pipe to a pond 34,000,000 liters (9,000,000 gal) in capacity for gravity settling. The overflow from this pond is treated in a series of four settling lagoons. Approximately 40 percent of the last lagoon overflow is sent back to the mill and the remainder is discharged to a brook near the property.

In facility 2033 the filtrate with a pH of 3.5-4.0, the flotation tailings with a pH of 10-10.5 and the primary thickener overflow are combined, and the resulting stream, having a pH of 4.5-5.5, is sent to a small sump in the facility for treating. The effluent pH is adjusted by lime addition to a 6.5-7.5 level prior to discharge into the settling pond. The lime is added by metered pumping and the pH is controlled manually. The effluent from the treating sump is routed to one end of a "U" shaped primary settling pond and is discharged into a secondary or back-up pond. The total active pond area is about 0.8 hectare (2 acres). The clarification pond occupies about 0.3 hectare (0.75 acre). The back-up pond (clarification pond) discharges to an open ditch running into a nearby creek. The non-contact cooling water in facilities 2031 and 2033 is discharged without treatment. Facility 2044 uses a 1.6 hectare (4 acres) settling pond to treat the waste water; the overflow from this pond is discharged. It has been estimated that the present settling pond will be filled within two years' time. This company has leased a new piece of property for the creation of a future pond.

As all process water at facility 2031 is impounded and lost by evaporation, there is no process water effluent out of this property. Facility 2035 a washing facility also has no discharge.

At facilities 2032, 2033, and 2044, the effluent consists of the overflow from their clarification or settling ponds. The significant constituents in these streams are reported to be as follows:

Waste Material Facility Number	2032	2033	2044
pH	7.2-8.5	5.6	7.0
TSS, mg/l	<20 (26)*	80 (8)*	100

*Contractor verification

The average amounts of TSS discharged in these effluents were calculated from the above data to be:

facility	kg/kkg product	(lb/1000 lb)
2032	<0.34	
2033	0.29	
2044	0.50	

GARNET

Facility 3037 recycles untreated pit water used in screening operations, and sends water from jigging operations to a settling pond before discharge. Waste water from flotation underflow at facility 3071 is first treated with caustic to stabilize the pH which was acidified from flotation reagents. Then the underflow is sent to a series of tailings ponds. The solids settle out into the ponds and the final effluent is discharged. Water from the dewatering screen is recycled to the heavy media facility. Effluent arising from flotation underflow at facility 3071 is discharged. The pH is maintained at 7. The suspended solids content averaged 25 mg/l.

DIATOMITE

All waste water generated in diatomite preparation at facility 5500 is evaporated. There is no process water, cooling, or mine pumpout discharge. Facilities 5504 and 5505 send waste water to settling ponds with water being recycled to the process at facility 5505 and evaporated and percolated to ground water at facility 5504. But in late 1974 a pump is being installed to enable facility 5504 to decant and recycle the water from the pond to the process. Thus, all of these diatomite operations have no discharge of any waste water.

The oversize fraction and dust fines waste is land-dumped on-site at facility 5500. The solids content of this land-disposed waste is silica (diatomite) in the amount of about 300,000 mg/l. The waste slurries from facilities 5504 and 5505 consisting of scrubber fines and dust are land-disposed with the solids settling into ponds. The solids content of these slurries is 24,000 mg/l for facility 5505 and 146,000 mg/l for facility 5504.

GRAPHITE

The waste streams associated with the operation are flotation tailings and seepage water. The tailings slurry at about 20 percent solids and at a near neutral pH (adjustment made for optimum flotation) is discharged to a partially lined 8 hectare (20 acre) settling pond. The solids settle rapidly and the overflow is discharged. The seepage water from the tailings pond, mine and extraneous surface waters are collected through the use of an extensive network of ditches, dams and sumps. The collected waste waters are pumped to a treatment facility where lime is added to neutralize the acidity and precipitate iron. The neutralized water is pumped to the tailings pond where the iron floc is deposited. The acid condition of the pond seepage results from the extended contact of water with the tailings which dissolve some part of the contained iron pyrites.

It is discharged into a stream that flows into the lake that serves as the intake water source for the facility. The effluent composition falls within the limits established by the Texas State Water Quality Board for the following parameters: flow; pH; total suspended solids; volatile solids; BOD; COD; manganese and iron. Facility measurements compared to the state limitations are:

	facility average mg/l	State Standards 24 hr. maximum mg/l	State Standards monthly average mg/l
Flow l/day (gal/day)		1,160,000 (300,000)	1,820,000 (480,000)
total solids	750	1600	1380
TSS	10	20	10
Volatile Solids	1	10	0.2
Mn	0.1	0.5	-
Total Fe	0.1	2	1
BOD	9	15	10
COD	20	20	15
pH	7.3-8.5	6.8	7.5

This facility has no problem meeting this requirement because of a unique situation where the large volume of tailings entering the pond assists the settling of suspended solids from the acid mine drainage treatment more than that normally expected from a well designed pond.

JADE

Waste waters generated from the wire saw, sanding, and polishing operations are sent to settling tanks where the tailings settle out, and the water is discharged onto the lawn where it evaporates and/or seeps into the ground. Solid wastes in the form of tailings which collect in settling tanks are eventually land-disposed as fill.

Water from the scrubber is sent to a settling tank and clear water is recycled to the scrubber. Cooling water is discharged onto the lawn with no treatment.

PRETREATMENT TECHNOLOGY

Most minerals operations have waste water containing only suspended solids. Suspended solids is a compatible pollution parameter for publicly-owned treatment works. However, most of these mining and processing operations are located in isolated regions and have no access to these treatment facilities. No instances of discharge to publicly-owned treatment facilities were found in the industry. In the relatively few instances where dissolved materials are a problem, pH control and some reduction of hazardous constituents such as fluoride would be required. Lime treatment is usually sufficient to accomplish this. Sulfides would require air oxidation or other chemical treatment.

SECTION VIII

COST, ENERGY, WASTE REDUCTION BENEFITS AND NON-WATER ASPECTS OF TREATMENT AND CONTROL TECHNOLOGIES

Cost information contained in this report was assembled directly from industry, from waste treatment and disposal contractors, engineering firms, equipment suppliers, government sources, and published literature. Whenever possible, costs are taken from actual installations, engineering estimates for projected facilities as supplied by contributing companies, or from waste treatment and disposal contractors quoted prices. In the absence of such information, cost estimates have been developed insofar as possible from facility-supplied costs for similar waste treatments and disposal for other facilities or industries.

Capital investment estimates for this study have been based on 10 percent cost of capital, representing a composite number for interest paid or return on investment required. All cost estimates are based on August 1972 prices and when necessary have been adjusted to this basis using the chemical engineering facility cost index.

The useful service life of treatment and disposal equipment varies depending on the nature of the equipment and process involved, its usage pattern, maintenance care and numerous other factors. Individual companies may apply service lives based on their actual experience for internal amortization. Internal Revenue Service provides guidelines for tax purposes which are intended to approximate average experience. Based on discussions with industry and condensed IRS guideline information, the following useful service life values have been used:

(1) General process equipment	10 years
(2) Ponds, lined and unlined	20 years
(3) Trucks, bulldozers, loaders and other such materials handling and transporting equipment.	5 years

The economic value of treatment and disposal equipment and facilities decreases over its service life. At the end of the useful life, it is usually assumed that the salvage or recovery value becomes zero. For IRS tax purposes or internal depreciation provisions, straight line, or accelerated write-off schedules may be used. Straight line depreciation was used solely in this report.

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Capital costs are defined as all front-end out-of-pocket expenditures for providing treatment/disposal facilities. These costs include costs for research and development necessary to establish the process, land costs when applicable, equipment, construction and installation, buildings, services, engineering, special start-up costs and contractor profits and contingencies. Most if not all of the capital costs are accrued during the year or two prior to actual use of the facility. This present worth sum can be converted to equivalent uniform annual disbursements by utilizing the Capital Recovery Factor Method:

$$\text{Uniform Annual Disbursement} = \frac{P\ i\ (1+i)\text{nth power}}{(1+i)\text{nth power} - 1}$$

Where P = present value (capital expenditure), i = interest rate, %/100, n = useful life in years

The capital recovery factor equation above may be rewritten as:

Uniform Annual Disbursement = P(CR - i% - n)

Where (CR - i% - n) is the Capital Recovery Factor for i% interest taken over "n" years useful life.

Land-destined solid wastes require removal of land from other economic use. The amount of land so tied up will depend on the treatment/disposal method employed and the amount of wastes involved. Although land is non-depreciable according to IRS regulations, there are numerous instances where the market value of the land for land-destined wastes has been significantly reduced permanently, or actually becomes unsuitable for future use due to the nature of the stored waste. The general criteria applied to costing land are as follows:

(1) If land requirements for on-site treatment/disposal are not significant, no cost allowance is applied.
(2) Where on-site land requirements are significant and the storage or disposal of wastes does not affect the ultimate market value of the land, cost estimates include only interest on invested money.
(3) For significant on-site land requirements where the ultimate market value and/or availability of the land has been seriously reduced, cost estimates include both capital depreciation and interest on invested money.

(4) Off-site treatment/disposal land requirements and costs are not considered directly. It is assumed that land costs are included in the overall contractor's fees along with its other expenses and profit.
(5) In view of the extreme variability of land costs, adjustments have been made for individual industry situations. In general, isolated, plentiful land has been costed at $2,470/hectare ($1,000/acre).

Annual costs of operating the treatment/disposal facilities include labor, supervision, materials, maintenance, taxes, insurance and power and energy. Operating costs combined with annualized capital costs equal the total costs for treatment and disposal. No interest cost was included for operating (working) capital. Since working capital might be assumed to be one sixth to one third of annual operating costs (excluding depreciation), about 1-2 percent of total operating costs might be involved. This is considered to be well within the accuracy of the estimates.

All facility costs are estimated for representative facilities rather than for any actual facility. Representative facilities are defined to have a size and age agreed upon by a substantial fraction of the manufacturers in the subcategory producing the given mineral, or, in the absence of such a consensus, the arithmetic average of production size and age for all facilities. Location is selected to represent the industry as closely as possibly. For instance, if all facilities are in northeastern U.S., typical location is noted as "northeastern states". If locations are widely scattered around the U.S., typical location would be not specified geographically. It should be noted that the unit costs to treat and dispose of hazardous wastes at any given facility may be considerably higher or lower than the representative facility because of individual circumstances.

Costs are developed for various types and levels of technology:

Minimum (or basic level). That level of technology which is equalled or exceeded by most or all of the involved facilities. Usually money for this treatment level has already been spent (in the case of capital investment) or is being spent (in the case of operating and overall costs).

B,C,D,E---Levels - Successively greater degrees of treatment with respect to critical pollutant parameters. Two or more alternative treatments are developed when applicable.

Rationale for Pollutant Considerations

(1) All non-contact cooling water is not included unless otherwise specified.
(2) Water treatment, cooling tower and boiler blowdown discharges are not included unless otherwise specified.
(3) The specific removal of dissolved solids is not included.
(4) Mine dewatering treatments and costs are generally considered separately from process water treatment and costs. Mine dewatering costs are estimated for all mineral categories for which such costs are a significant factor.
(5) All solid waste disposal costs are included as part of the cost development.

The effects of age, location, and size on costs for treatment and control have been considered and are detailed in subsequent sections for each specific subcategory.

INDIVIDUAL MINERAL WASTE WATER TREATMENT AND DISPOSAL COSTS

DIMENSION STONE

Of the sixteen facilities inspected, thirteen use settling ponds for removal of suspended solids from waste water, two had no treatment and the other facility uses a raked settling tank. Approximately one-third of these facilities have total recycle after settling. Pond settling and recycle costs are given in Table 15. Since pond cost is the major investment involved, cost for settling without recycling is similar. There was no discernible correlation between facility age and treatment technology or costs. Facility sizes ranged from 2,720 to 64,100 kkg/yr (3,000 to 70,650 tons/yr). Since pond costs vary significantly with size in the less than one acre category, capital costs may be estimated to be directly proportional to the 0.8 exponential of size and directly proportional for operating expenses. Waste water treatment cost details for the typical facility values at Level C are shown below. Level B costs are similar except for recycle equipment.

Production: 18,000 kkg/yr (20,000 tons/yr)
8 hr/day; 250 days/yr

Water Use and Waste Characteristics:

4,170 l/kkg (1,000 gal/ton) of product
2% of product in effluent stream
5,000 mg/l TSS in raw effluent
360 kkg/yr (400 tons/yr) waste, dry basis
280 cu. m. (10,000 cu. ft.) wet sludge per year
1,300 kg solids per cu. m. sludge (80 lb/cu. ft.)

Treatment: Recycle of wash water after passing through a one acre settling pond

Cost Rational:

Pond cost	$10,000/acre
Total pipe cost	$1/inch diam/linear ft.
Total pump cost	$100/HP
Power costs	$0.02/kwh
Maintenance	5% of capital
Taxes and insurance	2% of capital
Capital recovery factor	0.1627

TABLE 15

DIMENSION STONE TREATMENT COSTS

PLANT SIZE 18,000 KKG PER YEAR OF Product

PLANT AGE 50 YEARS PLANT LOCATION near population center

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		0	10,000	13,600		
ANNUAL CAPITAL RECOVERY		0	1,600	2,200		
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		0	900	950		
ANNUAL ENERGY AND POWER		0	200	400		
TOTAL ANNUAL COSTS $		0	2,800	3,550		
COST/ KKG product		0	0.16	0.20		
WASTE LOAD PARAMETERS (kg/ kkg of product)	RAW WASTE LOAD					
Suspended Solids	20	20	0.8	0		

LEVEL DESCRIPTION:

A — direct discharge
B — settling, discharge
C — settling plus recycle

All costs are cumulative.

CRUSHED STONE

WET PROCESS

A typical wet crushed stone operation is assumed to produce 180,000 kkg/yr (200,000 tons/yr). The assumed wash water usage is 1,000 l/kkg (240 gal/ton), and the assumed waste content is 6% of the raw material. The cost data are presented in Table 16.

Levels B and C involve simple settling, discharge, or recycle. The waste water is passed through a one acre settling pond and discharged or recycled back to the facility. The pond is dredged periodically and the sludge is deposited on site.

Level D involves settling with flocculants and recycle. The waste water is treated with a flocculant and passed through a one acre settling pond. The effluent is then recycled. It is rare that a flocculant would be needed to produce an effluent quality acceptable for recycle in a crushed stone operation.

Level B

Pond Cost	$10,000
Pumps and piping	4,500
Power	1,000
Pond cleaning	6,000
Taxes and insurance	400

Level C

Total pond cost	$10,000
Total pump and piping cost	9,000
Annual capital recovery	3,100
Power	2,000
Pond cleaning	6,000
Taxes and insurance	400

Level D

Additional capital flocculant equipment	$ 3,500
Additional annual capital	600
Annual chemical cost	1,000

Granite fines (non-carbonate) settle somewhat slower than limestone fines (carbonate). As a result, recirculation granite ponds generally run about 50% larger than those of limestone for the same capacity facility. The amount of waste in the effluent is largely dependent on the type of

TABLE 16

CRUSHED STONE (WET PROCESS) TREATMENT COSTS

PLANT SIZE 180,000 KKG PER YEAR OF Crushed Stone

PLANT AGE 40 YEARS PLANT LOCATION rural location near population center

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		0	14,500	19,000	22,500	
ANNUAL CAPITAL RECOVERY		0	2,400	3,100	3,700	
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		0	6,400	6,400	7,400	
ANNUAL ENERGY AND POWER		0	1,000	2,000	2,000	
TOTAL ANNUAL COSTS $		0	9,800	11,500	13,100	
COST/ KKG product		0	0.054	0.064	0.073	
WASTE LOAD PARAMETERS (kg/ kkg of product)	RAW WASTE LOAD					
Suspended Solids	60	60	0.2	0	0	

LEVEL DESCRIPTION:

A — direct discharge
B — settling pond, discharge
C — settling pond, recycle
D — flocculant, settling pond, recycle

All costs are cumulative.

product. Six percent waste solids was chosen as an average value. The range of wastes is 2 to 12 percent. The cost to treat per ton of product is approximately proportional to percent waste. The amount of stone washed in any given year varies with the demand for a washed product. The capital costs for treatment are more readily absorbed when a large portion of the stone is washed. Capital costs are estimated to be directly proportional to the 0.9 power of size and operating expenses are proportional to size.

MINE DEWATERING

Two typical pumpout rates are assumed for mine dewatering of crushed stone plants. The cost data are presented in Tables 16A and 16B.

Level A involves enlarging a 1 acre-ft. quarry floor sump to accomodate a 1 acre-ft, 2-stage sump separated by a gravel/rock barrier (filter). The quarry is dewatered by pumping from the second stage with existing pumps and lines to the surface. Sump berms and filter are constructed from on-site materials, using earth-moving equipment, etc., available from the mining operations. A small amount of new pipe is needed to relocate the sump pump in the new second stage sump. Annual cleanout will be required on the new second stage sump, as well as the old first stage.

Level B involves construction of a settling pond outside the quarry at surface level and construction of a sump discharge line to the pond. Berm and dam materials are obtained from the excavation of the pond. The earth moving equipment is that used in the mining operation. The settling pond discharges by gravity. The existing quarry floor sump and sump pump are used. The existing sump discharge line is used and additions are made to it.

Level C involves the same new construction as Level B, except anionic chemical flocculant is added to the sump discharge to the settling pond.

Level D is the same as Level C, except the pH is adjusted by chemical addition from pH 5 to pH 7.

BASIS FOR COST

There are 4800 facilities in this category of which 59 percent wash their product. Of those that wash their product, an estimated 68 percent practice recycle of process water. Thirteen percent of the facilities do not have mine water. There are 1920 crushed stone facilities representing production of 307 million kkg (338 million tons) that are

TABLE 16 A

COST-BENEFIT ANALYSIS FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY CRUSHED STONE

PLANT SIZE 1,455 METRIC TONS PER ~~YEAR~~ DAY OF C.S. (1,600 TPD)

PLANT AGE _____ YEARS PLANT LOCATION 1020

Pumpout = 70 GPM
250 days/yr. operation
363,750 metric tons/yr

		LEVEL				
		A ~~(MIN)~~	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		1,492	3,485	15,800	24,700	
ANNUAL CAPITAL RECOVERY		176	411	2,419	3,867	
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		1,015	1,023	4,832	8,879	
ANNUAL ENERGY AND POWER		-	-	11	22	
TOTAL ANNUAL COSTS		1,191	1,434	7,270	12,770	
COST/METRIC TON C.S.		0.003	0.004	0.020	0.035	
WASTE LOAD PARAMETERS ~~(kg/metric ton of _____)~~	RAW WASTE LOAD					
TSS, mg/1	200	30	<30	< 30	<30	
pH	5.0	5.0	5.0	5.0	6-9	
Acidity, mg/1 $CaCO_3$	190	190	190	190	0	

LEVEL DESCRIPTION:

A = added 2nd stage sump, rock filter
B = settling pond at surface
C = B + floc treatment
D = C + pH control

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TABLE 16 B

COST-BENEFIT ANALYSIS FOR A REPRESENTATIVE PLANT
(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY CRUSHED STONE

PLANT SIZE 1,451 METRIC TONS PER DAY OF C.S. (1,600 TPD)

PLANT AGE ____ YEARS PLANT LOCATION 1022

600 GPM pumpout
250 days/yr. operation
362,750 metric tons/yr

		LEVEL				
		A	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		4,654	17,455	41,200	57,680	
ANNUAL CAPITAL RECOVERY		549	2,060	5,923	8,616	
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		1,125	1,162	6,247	13,252	
ANNUAL ENERGY AND POWER		-	-	96	192	
TOTAL ANNUAL COSTS		1,674	3,222	12,266	22,060	
COST/METRIC TON C.S.		0.005	0.009	0.034	0.061	
WASTE LOAD PARAMETERS ([illegible])	RAW WASTE LOAD					
TSS, mg/l	200	30	<30	<30	<30	
pH	5.0	5.0	5.0	5.0	6-9	
Acidity, mg/l $CaCO_3$	190	190	190	190	0	

LEVEL DESCRIPTION:

A = 2nd Stage sump, rock filter added
B = Settling pond at surface
C = B + floc treatment
D = C + pH control

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CONSTRUCTION SAND AND GRAVEL

DRY PROCESS

A typical dry process sand and gravel facility produces 450,000 kkg/yr (500,000 tons/yr) of construction sand and gravel. There is no process water use, no non-contact cooling water and usually no pit pumpout. Since there is no water use or waste water generated, treatment is not required. Pit pumpout is required at some facilities during periods of high rainfall. Some facilities also have a non-contact cooling water discharge. The pit pumpout in some of these cases is settled in a sump or pond. Age, location, and production have no consistent effect on waste waters from facilities in this subcategory, or on costs to treat them. There are an estimated 750 facilities in this subcategory representing a production of 129 x 10^6 kkg/yr (143 x 10^6 tons/yr).

WET PROCESS

The average production rate of facilities in this subcategory is 130,000 kkg/yr (143,000 tons/yr). Median facility size is approximately 227,000 kkg/yr (250,000 tons/yr). This is selected as representative for facility size. The assumptions used in costing are that: 10 percent of raw material is in the waste stream (68,000 mg/l), 11,400 l/min (3,000 gal/min) is used for washing, and all particles down to 200 mesh (74 micron) are recovered for sale by screw classifier cyclones, etc. The costs are listed in Table 17.

Level B: 5.6 acre settling pond and discharge of effluent.

Pond cost	$28,000
Pump cost	2,000
Pipe cost	3,000
Annual power	300
Taxes and insurance	800
Maintenance	800

Level C: 5.6 acre settling pond followed by recycle of waste water.

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TABLE 17

CONSTRUCTION SAND AND GRAVEL (WET PROCESS) TREATMENT COSTS

PLANT SIZE 227,000 KKG PER YEAR OF product

PLANT AGE 5 YEARS PLANT LOCATION near population center

		LEVEL						
		A (MIN)	B	C	D	E	F	G
INVESTED CAPITAL COSTS: $								
TOTAL		0	33,000	37,000	40,000	50,000	180,000	21,600
ANNUAL CAPITAL RECOVERY		0	5,400	6,000	5,200	8,100	29,200	2,600
OPERATING AND MAINTENANCE COSTS: $								
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		0	1,600	2,000	21,000	29,200	41,400	28,100
ANNUAL ENERGY AND POWER		0	300	600	600	400	600	400
TOTAL ANNUAL COSTS $		0	7,300	8,600	26,800	37,700	71,200	31,100
COST/ KKG product		0	0.03	0.04	0.12	0.17	0.31	0.14
WASTE LOAD PARAMETERS (kg/ kkg of product)	RAW WASTE LOAD							
Suspended Solids	100	100	0.4	0	0	0	0	0

All costs are cumulative.

LEVEL DESCRIPTION:

A — direct discharge
B — settling, discharge
C — settling, recycle
D — two silt removal ponds, settling pond, recycle
E — flocculant, mechanical thickener and recycle. Transportation of sludge to disposal basin.
F — flocculant, inclined plate settlers, and recycle effluent. Transport sludge to disposal basin.
G— flocculant, settling basin, recycle

Total pond cost	$28,000
Total pump cost	3,000
Total pipe cost	6,000
Power	600
Taxes and insurance	1,000
Maintenance	1,000

Level D: Two silt removal ponds of 0.04 ha (0.1 acre) each are used alternately prior to the main settling pond of 5.6 acres. The life of the main pond is greatly increased as most of the solids are removed in the primary ponds. One small pond is dredged while the other is in use. The sludge is deposited on site.

Total pond cost	$30,000
Annual pond cost	3,600
Total pump and piping	10,000
Annual pump and piping	1,600
Annual dredging and sludge disposal	20,000
Power	600
Taxes and insurance	1,000

Level E: A mechanical thickener is used along with a flocculating agent to produce an effluent of 250 mg/l for recycle. The underflow sludge is transported to a 4 acre sludge disposal basin at a cost of $1.1/kkg ($1/ton)

Total thickener cost	$ 18,500
Sludge disposal basin cost	20,000
Polymer feed system cost	1,600
Pump and piping	9,700
Annual sludge transportation	25,000
Annual chemical cost	2,200
Annual power	400
Maintenance	1,000
Taxes and insurance	1,000

Level F: Inclined plate settlers are used to produce an effluent of 250 mg/l which is recycled back to the process. A coagulant is added prior to the settlers to increase settling rate. The underflow sludge is transported to a 4 acre settling basin at a cost of one dollar per ton of solids. It should be noted that no case of an inclined plate settler successfully treating a sand and gravel waste was found. The advantage of this system is the small area required.

Inclined plate settler cost	$150,000
Pumping and piping	10,000
Sludge disposal basin	20,000
Sludge transportation	25,000
Chemical	2,000
Maintenance	7,200
Taxes and insurance	7,200
Power	600

Level G: Flocculant added, 1 acre settling pond is used for treatment, and effluent is recycled to the process. The sludge is dredged and deposited on site at a cost of $0.55/kkg ($0.50/ton).

Total pond cost	$ 10,000
Polymer mixing unit	1,600
Pump and piping	10,000
Chemical cost	2,200
Dredging	25,000
Power	400
Taxes and insurance	900

The production rate in this subcategory varies from 10,900 to 1,800,00 kkg/yr (12,000 to 2,000,000 tons/yr). The waste volume and water flow vary proportionately with production. As a result, the necessary settling area varies proportionately with production. The necessary pond capacity also varies proportionately with sludge volume, and thus production. Pumping, piping and power costs may also be considered to be roughly proportional to water flow, and production. Thus, the capital costs for Levels B, C, D, and G are estimated to be directly proportional to the 0.9 power of size. Operating costs not related to capital are approximately directly proportional to size. Levels E and F use equipment for clarification rather than ponds. Capital costs for them should be directly proportional to the power of 0.7 to size. Operating costs not based on capitalization are approximately directly proportional to size.

A facility having a waste content other than ten percent should require a proportionately different water usage. The settling area required to obtain recyclable effluent should be proportional to waste content. Dredging and pumping are also proportional to waste content. Thus the treatment cost per ton of product should vary roughly proportionately with waste content. Waste content can vary from less than 5% to 30%.

A canyon or hillside can greatly reduce the cost of pond building. Also, a wet land can increase the cost of building a pond.

A suspended solids average particle size greater than the one shown would mean a proportionately smaller settling area would be need to produce recyclable effluent. A smaller particle size could be countered with the use of a flocculant, if necessary.

An increase in settling rate would require a proportionately smaller settling area. A settling rate increase due to the use of coagulant of 100 times was assumed, based on laboratory tests and industry supplied information.

There are an estimated 4,250 facilities in the wet processing subcategory, producing 519 million kkg/yr (573 million tons/yr). Of these, an estimated 50% (2,125 facilities) are presently recycling their effluent. Another estimated 25% (1,063 facilities) have no discharge under normal conditions due to evaporation and/or percolation in settling ponds. The remaining 25% (1,063 facilities) presently have a discharge. It is estimated that 90% of the facilities having a discharge (956 facilities) presently have a ponding system. These latter facilities could in most cases convert their ponds to a recycle system by installing pumps and pipe, with the use in some cases of a coagulant.

Thus the facilities in this subcategory without present ponding systems are estimated to be 2.5% (107 facilities). Almost all of these facilities could install treatment options C, D, or G, which are the least expensive. Options E or F would only be required in an urban environment where sufficient settling area is not available on site.

The 956 facilities with settling pond discharges produce an estimated 152 million kkg/yr (168 million tons/yr). The installation of a pump and piping system, and the addition of a flocculant would result in a total annual cost per ton of $0.02/kkg ($0.018/ton), or the total capital expenditure required represents about 7.4 million dollars.

The 107 facilities which are presently discharging without treatment produce an estimated 16 million kkg/yr (18 million tons/yr). The facilities not having any ponds could achieve recycle for a capital cost of 1.7 million dollars. It is assumed that these facilities may achieve recycle for an average annualized cost of $0.11/kkg ($0.10/ton). It should be noted that a small fraction of these 107 facilities have no land for settling ponds, and that no sand and gravel facility utilizing options E or F (no ponds) to achieve recycle was found.

The entire subcategory of wet processed sand and gravel could eliminate discharge of process effluent for a total capital expense of about 10 million dollars. The average cost of production would rise $0.019/kkg ($0.017/ton).

RIVER DREDGING, ON-LAND PROCESS

A production of 360,000 kkg/yr (400,000 tons/yr) was assumed. The same treatment options apply as in wet process facility. Costs of waste water treatment for the typical facility can be derived from these presented in Table 17 by applying the appropriate size factors. Factors affect treatment and costs in the same manner as described for wet processing.

There are an estimated fifty river dredging operations with on-land processing, producing 13,300,000 kkg/yr (16,700,000 tons/yr) of sand and gravel. An estimated 50% of the facilities producing 50% of the volume have no point source discharge at this time. It is estimated that twenty-two of the remaining twenty-five facilities have settling ponds at the present time. Recycle should be achievable with the aid of a flocculant for an increased production cost of $0.02/kkg ($0.018/ton). The total capital cost for the subcategory is estimated to be $1,500,000. The average increase in production costs would be $0.011/kkg ($0.01/ton).

INDUSTRIAL SAND

DRY PROCESSING

Approximately 10 percent of the industrial sand operations fall into this subcategory. The only water involved comes from dust collectors used by some facilities. Of the five dry process facilities surveyed, two have such scrubbers - one without treatment and the other with pond settling and complete recycle. Treatment is by addition of 5 mg/l flocculating agent and recycle through a one acre settling pond.

Assumptions:

167,000 l/day (44,000 GPD) scrubber water
5 days/week; 8 hours/day
flocculant cost - $1/lb
piping cost - $1/inch diam/linear foot
pump cost - $1/HP/yr
power cost - $.02/kwh
pond cost - $10,000/acre
TSS in raw waste - 30,000 mg/l
pond cleaning - $0.5/ton of sludge

Capital Costs:

pond	$10,000
piping and pump	3,000
polymer mixing unit	1,500
total capital	14,500
annual capital recovery	2,360

Operating Costs:

pond cleaning	$ 700
power	150
chemical	50
maintenance	725
taxes and insurance	290
total annual operating	1,700
total annual recycle costs	$4,000

WET PROCESS

The wet process uses washing and screening operations are similar to those for construction sand and gravel. Treatment of the waste water is also the same. By use of ponds, thickeners and clarifiers, three out of the four wet process facilities studied have no discharge of process water. Table 18 summarizes the costs for two treatment technologies.

Level A: 39 acre settling pond, discharge effluent

pond cost	$60,000
pump cost	3,000
piping cost	6,000

Level B

Capital Costs

settling pond area	39 acres
pond cost	$60,000
pump costs	6,000
piping costs	13,500
total capital	$79,500

Annual Investment Costs

pond costs (20 yr life @ 10% interest) = $7000
pump costs (5 yr life @ 10% interest) = 1500
piping costs (10 yr life @10% interest) = 2200
total $10,700

Operating Costs

maintenance costs @ 2% of capital = $1600
power cost @ $.02 per kwh = 2000
taxes and insurance @ 2% of capital = 1600
total $5200

TABLE 18

INDUSTRIAL SAND (WET PROCESS) TREATMENT COSTS

PLANT SIZE 180,000 KKG PER YEAR OF product

PLANT AGE 10 YEARS PLANT LOCATION near population center

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		69,000	79,500	155,000		
ANNUAL CAPITAL RECOVERY		8,000	10,700	25,200		
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		2,800	3,200	21,900		
ANNUAL ENERGY AND POWER		1,000	2,000	2,000		
TOTAL ANNUAL COSTS $		11,800	15,900	49,100		
COST/ KKG product		0.07	0.09	0.26		
WASTE LOAD PARAMETERS (kg/ kkg of product)	RAW WASTE LOAD					
Suspended Solids	35	0.7	0	0		

LEVEL DESCRIPTION:

All costs are cumulative.

A — settle, discharge
B — settle, recycle
C — mechanical thickener with coagulant, overflow is recycled to process. Underflow is passed through a settling basin. Effluent from the settling basin is also recycled to process.

Level C

Capital Costs

settling pond area	-	39 acres
pond costs	-	$60,000
polymer feed system	-	5,000
thickener	-	60,000
pump costs	-	15,000
piping costs	-	15,000
total		$155,000

total annual capital costs (10 years @ 10%) = $25,200

Operating Costs

chemicals	$11,000
maintenance @ 5% of capital	7,800
power	2,000
taxes and insurance @ 2% of capital	3,100
total	$23,900

The facilities surveyed for this subcategory have ages from one to 20 years. There is no discernable correlation of treatment costs with facility age. Production capacities range from 54,000 to 900,000 kkg/yr (60,000 to 1,000,000 tons/yr). Treatment technology Levels A and B, involving pond costs, should show slight unit cost variation (0.9 power). Level C technology with a mechanical thickener as well as a pond are estimated to be directly proportional to the 0.7 exponent of size. Operating costs other than taxes, insurance and annualized capital costs are estimated to be directly proportional to size.

ACID AND ALKALINE FLOTATION

There are three types of flotation processes used for removing impurities from industrial sands:

(1) Acid flotation to effect removal of iron oxide and ilmenite impurities,

(2) Alkaline flotation to remove aluminate bearing materials, and

(3) Hydrofluoric acid flotation for removal of feldspar.

These three flotation processes have been subdivided into two subcategories; (1) acid and alkaline flotation and (2) hydrofluoric acid flotation. Subcategory (1) is discussed in this subsection and subcategory (2) in the following subsection.

Four surveyed acid flotation facilities have no effluent discharge. One alkaline flotation facility has effluent waste water similar in composition to the intake stream. Recycle costs for acid and alkaline flotation waste water are given in Table 19.

Cost Basis For Table 19:

(1) production - 180,000 kkg/yr (200,000 tons/yr)
(2) the process waste water is treated with lime, pumped to a holding pond and recirculated back to the facility. The holding pond is one-half acre and is cleaned once every ten years.

Capital Costs

lime storage and feed system	-	$75,000
reaction tank	-	40,000
pumps and piping	-	20,000
Total		$ 135,000

annualized capital cost (10 yr life @ 10%) $22,000

Operating Costs

chemical costs	-	$11,000
maintenance @ 5% of capital	-	7,300
power	-	2,000
taxes and insurance @ 2% of capital	-	2,900
total		$23,200

Surveyed facilities in this subcategory ranged in age from one to 60 years. There was no discernable correlation between treatment costs and facility age.

Facilities in this subcategory range between 19,000 to 1,360,000 kkg/yr (54,000 to 1,500,000 tons/yr). Costs/acre of small ponds change significantly with size. Also, the chemical treatment facilities costs are estimated to be directly proportional to the 0.6 power of size. Taken together, capital costs are estimated to be directly proportional to the 0.7 exponent of size. Operating costs, except for taxes, insurance and other capital related factors may be expected to be directly proportional to size.

TABLE 19

INDUSTRIAL SAND (ACID AND ALKALINE PROCESS) TREATMENT COSTS

PLANT SIZE 180,000 KKG PER YEAR OF product

PLANT AGE 30 YEARS PLANT LOCATION southeastern U.S.

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		115,000	135,000			
ANNUAL CAPITAL RECOVERY		18,700	22,000			
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		19,000	21,200			
ANNUAL ENERGY AND POWER		1,000	2,000			
TOTAL ANNUAL COSTS $		38,700	45,200			
COST/ KKG product		0.22	0.25			
WASTE LOAD PARAMETERS (kg/ kkg of product)	RAW WASTE LOAD					
Suspended Solids	100	0.4	0			

LEVEL DESCRIPTION:

A — neutralize, settle, discharge
B — neutralize, settle, recycle

All costs are cumulative.

HF FLOTATION

Unlike the acid and alkaline flotation processes where total recycle is either presently utilized or believed to be feasible, waste water from the HF flotation process is of questionable quality for total recycle. Estimated costs for partial recycle are given in Table 20. Only one such facility is known.

Cost Basis For Table 20:

(1) production: 180,000 kkg/yr (200,000 tons/yr)
(2) all waste waters are fed to a thickener to remove suspended materials. The overflow containing 90 percent of the water is recycled to the process, the underflow is fed to a settling pond for removal of solid wastes and pH adjustment prior to discharge.

Capital Costs

pond - 1/2 acre x 10 ft depth @ $20,000/acre	=	$ 10,000
lime storage and feed system	=	30,000
thickener	=	60,000
pump costs	=	5,000
piping costs	=	15,000
total		$120,000

annualized investment costs (10 yr life @ 10% interest)

$120,000 x .1629 = $19,500

Operating Costs

maintenance @ 5% of capital	=	$6,000
chemicals, lime @ $20/ton	=	11,000
power @ $.0 2/kwh	=	2,000
taxes and insurance @ 2% of capital	=	2,400
total		$23,400

TABLE 20

INDUSTRIAL SAND (HF FLOTATION) TREATMENT COSTS

PLANT SIZE 180,000 KKG PER YEAR OF product

PLANT AGE -- YEARS PLANT LOCATION California

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		120,000	200,000			
ANNUAL CAPITAL RECOVERY		19,500	32,500			
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		21,400	21,400			
ANNUAL ENERGY AND POWER		2,000	2,000			
TOTAL ANNUAL COSTS $		42,900	55,900			
COST/ KKG product		0.23	0.31			
WASTE LOAD PARAMETERS (kg/ kkg of product)	RAW WASTE LOAD					
Suspended Solids	135	0.044	0			
Fluoride	0.45	0.005	0			

LEVEL DESCRIPTION:

A — 90% of wastewater removed in thickener and recycled to process. Underflow from thickener fed to settling pond for removal of tailings and pH adjustment prior to discharge.

B — segregate HF waste water, pond and evaporate; recycle other water after ponding.

All costs are cumulative.

ACID LEACHING

Treatment cost for this process is not completed at this time, and no treatment recommendation will be made till further study is made.

GYPSUM

Gypsum is mined at sixty-five sites in the United States. An estimated 57 of these facilities use no contact water in their process. Two known facilities use heavy media separation and washing to beneficiate the crude gypsum ore, which results in a process effluent.

DRY PROCESS

There is no contact process water in this category, thus there are no waste water treatment costs.

WET SCRUBBERS

Since the contractor's study, no plant in this subcategory discharges process waste water.

HEAVY MEDIA SEPARATION

Both facilities presently recycle process waste water after settling pond treatment. In one of the facilities an abandoned mine is utilized as the settling pond. Capital investment for the system is estimated to be $15,000. Annual operating cost is estimated to be $10,000. Total annualized recycle costs are estimated to be $12,500. This results in a recycle cost of $0.05/kkg of gypsum produced ($0.045/ton).

MINE DRAINAGE

In all of the subcategories some facilities find it necessary to pump out their quarries because of rainwater collection. No facility is presently treating its mine pumpout water other than what clarification occurs in a sump, and the average effluents are all below 25 mg/l. Insofar as it is known there is no cost to treat the pit pumpout.

ASPHALTIC MINERALS

Of the asphaltic minerals, bituminous limestone, oil-impregnated diatomite and gilsonite, only gilsonite operations currently have any discharge to surface water. For gilsonite, present mine water drainage treatment consists of pond settling of suspended solids prior to discharge. Process water is discharged untreated. Costs for present treatment are an estimated $0.08/kkg of gilsonite produced ($0.07/ton). Completion of treatment facilities currently under construction will result in no discharge of waste water from the property at a cost of $1.10/kkg ($1/ton) of gilsonite produced. The cost estimates are given in Table 21. The only gilsonite facility is located in Utah. All costs are specific for this facility.

Level A

Capital Costs

pond cost, $/hectare ($/acre): 24,700 (10,000)
settling pond area, hectares (acres): 0.8 (2)
pump, piping, ditching: $5,000

Operating and Maintenance Costs

taken as 2% of capital costs

Level B

Capital Costs

pond costs - same as Level A	
sand filters -	$150,000
pumps and piping -	40,000
electrical and instrumentation	25,000
roads, fences, landscaping -	15,000

Operating and Maintenance Costs

labor - 1/2 man @ $10,000/yr	$ 5,000
maintenance labor and materials @ 4% of investment	10,000
power @ $.01/kw-hr	500
taxes and insurance @ 2% of investment	5,000

TABLE 21

GILSONITE TREATMENT COSTS

PLANT SIZE 45,450 KKG PER YEAR OF Gilsonite

PLANT AGE 50 YEARS PLANT LOCATION Utah

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		25,000	250,000			
ANNUAL CAPITAL RECOVERY		2,940	29,400			
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		500	20,000			
ANNUAL ENERGY AND POWER		200	500			
TOTAL ANNUAL COSTS $		3,640	49,900			
COST/ KKG Gilsonite		0.08	1.10			
WASTE LOAD PARAMETERS	RAW WASTE LOAD					
Mine Pumpout:						
Suspended Solids, mg/liter		3,375	0			
BOD, mg/liter		12	0			
Process Water:						
Suspended Solids, mg/liter		17	0			
BOD, mg/liter		43	0			

LEVEL DESCRIPTION:

A — pond settling of suspended solids in mine pumpout; no treatment of process water (present minimum).

B — combining of mine pumpout and process water followed by pond settling, filtration and partial recycle. Discharge from recycle to be used for on-property irrigation.

ASBESTOS AND WOLLASTONITE

Asbestos is mined and processed at five locations in the U.S., two in California, and one each in Vermont, Arizona and North Carolina. One facility in California uses wet processing while the remaining four facilities use a dry process. There is also one wollastonite dry facility which has no process water. The wet process facility discharges twenty percent of the process water 155,200 l/day (41,000 gal/day) to two percolation/evaporation ponds. The ponds total less than one half acre in size. The total capital investment for the percolation ponds was estimated to be $2,000. Annual operating and maintenance is estimated to be $1,000. The total annualized cost is estimated to be $1,325 for the percolation/evaporation ponds. One pond serves as an overflow for the other, therefore, surface water discharge almost never occurs. The ponds are dredged once annually.

Sixty-eight percent of the water in the wet process facility is recycled via a three acre settling pond. A natural depression is utilized for the pond, and dredging has not been necessary. The water recirculated amounts to 529,900 l/day (140,000 gal/day). Annualized cost for the recirculation system is estimated to be $2,500. The remaining twelve percent of the process water is retained in the product and tailings. Total annualized water treatment costs for wet processing of asbestos are estimated to be $3,825, which results in a cost of $0.09/kkg of asbestos produced ($0.08/ton).

All five operations accumulate waste asbestos tailings at both facility and the mining site. These tailings are subject to rainwater runoff. At two sites dams have been built to collect rainwater and create evaporation/percolation ponds. The total capital investment at each site is estimated to be $500. Operating and maintenance costs for these dams are considered to be negligible. Natural canyons were utilized in both cases to create the ponds. One facility because of its geological location must discharge water collected in its mine. The alkaline groundwater in the area requires the water to be treated by addition of 0.02 mg/l sulfuric acid before discharge. The pumping costs for this operation are considered to be part of the production process. The chemical costs are less than $100/yr. The estimated capital cost for total impoundment of mine water to eliminate the discharge is $15,000.

LIGHTWEIGHT AGGREGATE MINERALS

PERLITE

All U.S. perlite facilities are in southwestern U.S. and the processes are all dry. Since there is no water used, there is no waste water generated or water treatment required. One investigated mine does dewater the quarry when water accumulates, but this water is evaporated on land at estimated cost of $0.01 to $0.05/kkg (or ton) of perlite produced.

PUMICE

At most facilities, there are no waterborne wastes as no water is employed. At one facility there is scrubber water from a dust control installation. The scrubber water is sent to a settling pond prior to discharge. Because of the relatively small amount of water involved and the large production volume of pumice per day, treatment costs for this one facility are roughly estimated as less than $0.05/kkg (or ton) of pumice produced at that facility.

VERMICULITE

Two facilities represent almost all of the total U.S. production. Both of these facilities currently achieve no discharge of pollutants by means of recycle, pond evaporation and percolation. Detailed costs for a typical facility are given in Table 22. The ages of the two facilities are 18 and 40 years. Age is not a cost variance factor. One facility is located in Montana and the other in South Carolina. In spite of their different geographical location, both are able to achieve no discharge of pollutants by the same general means and at roughly equivalent costs. Facility sizes range from 109,000 to 209,000 kkg/yr (120,000 to 230,000 tons/yr). Since pond costs per acre are virtually constant in the size range involved, waste water treatment costs may be considered directly proportional to facility size and therefore invariant on a cost/ton of product basis. Capital and operating costs were taken from industry reported values. The basis of these values is shown as follows:

Assumptions:

Production:	157,000 kkg/yr (175,000 tons/yr)
Process Water Use:	8,350 l/kkg (2,000 gal/ton)
Treatment:	settling ponds and recycle of process water
Capital Cost:	$325,000
Operating Costs:	$ 45,000/yr
Annual Capital Recovery:	$ 52,900

TABLE 22

VERMICULITE TREATMENT COSTS

PLANT SIZE 160,000 KKG PER YEAR OF product

PLANT AGE 30 YEARS PLANT LOCATION Montana or South Carolina

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		325,000				
ANNUAL CAPITAL RECOVERY		52,900				
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		40,000				
ANNUAL ENERGY AND POWER		5,000				
TOTAL ANNUAL COSTS $		97,900				
COST/ KKG product		0.62				
WASTE LOAD PARAMETERS (kg/ kkg of product)	RAW WASTE LOAD					
Suspended Solids	1,600	0				

All costs are cumulative.

LEVEL DESCRIPTION:

A — recycle, evaporation and percolation.

MICA

There are seven significant wet mica beneficiation facilities in the U.S., seven dry grinding facilities processing beneficiated mica, and three wet grinding facilities. There are also several western U.S. operations using dry surface mining. They have some mine water drainage. Treatment for this mine water is estimated as $0.19/kkg ($0.2/ton) (based on a 1/2 acre pond @ $10,000/acre and operating costs of $750/yr).

WET BENEFICIATION PLANTS

Eastern U.S. beneficiation facilities start with matrices of approximately 10 percent mica and 90 percent clay, sand, and feldspar combinations. Much of the non-mica material is converted to saleable products, but there is still a heavy portion which must be stockpiled or collected in pond bottoms. The variable nature of the ore, or matrix, leads to several significant treatment/cost considerations. Treatment costs and effluent quality differ from facility to facility. Additional saleable products reduce the cost impact of the overall treatment systems developed. Solids disposal costs are often a major portion of the overall treatment costs, particularly if they have to be hauled off the property.

All of these factors can change the overall treatment costs per unit of product of Table 23 by at least a factor of two in either direction. The known ages for four of the seven facilities range from 18 to 37 years. There is no significant treatment cost variance due to this range. The sizes range from 13,600 to 34,500 kkg/yr (1,500 to 3,800 tons/yr). The unit costs given are meant to be representative over this size range on a unit production basis.

TABLE 23

MICA TREATMENT COSTS

PLANT SIZE 16,360 KKG PER YEAR OF Mica

PLANT AGE 27 YEARS PLANT LOCATION Southeastern U.S.

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		150,000	275,000	300,000	245,000	245,000
ANNUAL CAPITAL RECOVERY		17,600	32,300	35,200	39,900	39,900
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		50,000	64,500	68,000	74,400	74,400
ANNUAL ENERGY AND POWER		2,000	3,000	5,000	5,000	5,000
TOTAL ANNUAL COSTS $		69,600	99,800	108,200	119,300	119,300
COST/ KKG Mica		4.3	6.1	6.6	7.3	7.3
WASTE LOAD PARAMETERS (kg/ kkg of Mica)	RAW WASTE LOAD					
Suspended Solids	2,100	2.5-6	1.2-2.5	0	1.2-2.5	0
pH	--	6-9	6-9	-	6-9	-

LEVEL DESCRIPTION:

All costs are cumulative

A — minimum level ponding
B — extended ponding and chemical treatment
C — closed cycle pond system (no discharge)
D — mechanical thickener and filter
E — closed cycle thickener and filter system (no discharge)

Treatment Level A - Pond settling of process wastes (minimum treatment)

(1) Production rate - 16,400 kkg/yr (18,000 ton/yr)

(2) Solid wastes ponded - 34,200 kkg/yr (38,000 ton/yr)

(3) Solid waste stockpiled - 45,000 kkg/yr (50,000 ton/yr)

(4) Pond size - 4 hectares (10 acres)

(5) Effluent quality
   (a) suspended solids - 20-50 mg/l
   (b) pH - 6-9

(6) Waste water effluent - 5.7 x 10^6 l/day (1.5 mgd)

Capital Costs

Ponds	=	$100,000
Pumps and piping	=	35,000
Miscellaneous constructions	=	15,000
Total	=	$150,000

Assume 20 yr life and 10% interest
capital recovery factor = .1174

Annual investment costs = $17,610/yr

Operating Costs

Solid wastes handling @ $0.30/ton	=	$15,000
Pond cleaning @ $0.50/ton	=	19,000
Maintenance	=	10,000
Power	=	2,000
Labor	=	3,000
Taxes and insurance @ 2% of capital	=	3,000
Total		$52,000

Treatment Level B - Pond settling of process wastes and chemical treatment

The basis is the same as for Level A, except

(1) Pond size - 8 hectares (20 acres)
(2) Chemical treatments - lime, acid and flocculating agents used as needed
(3) Effluent quality
    (a) suspended solids - 10-20 mg/l
    (b) pH - 6-9

Capital Costs

Ponds = $200,000
Pumps and piping = 50,000
Miscellaneous construction = 25,000
Total $275,000

Annual investment costs = $32,285/yr

Operating Costs

Solid wastes handling @ $0.30/ton = $15,000
Pond cleaning @ $0.50/ton = 19,000
Maintenance = 15,000
Chemicals = 5,000
Power = 3,000
Labor (misc) = 5,000
Taxes and insurance @ 2% of capital = 5,500
Total $67,500

Treatment Level C - Total recycle of process water using pond system

Basis: Same as Level B except no discharge

Capital Costs

Ponds = $200,000
Pumps and piping = 75,000
Miscellaneous construction = 25,000
Total $300,000

Annual investment costs = $35,220

Operating Costs

Solids wastes handling @ $0.30/ton	=	$15,000
Pond cleaning @ $0.50/ton	=	19,000
Maintenance	=	20,000
Chemicals	=	5,000
Power	=	5,000
Labor	=	3,000
Taxes and insurance @ 2% of capital	=	6,000
Total		$73,000

Treatment Level D - Thickener plus filter removal of suspended solids. Generally pond systems are the preferred system for removing suspended solids from waste water. In some instances, however, when the land for ponds is not available or there are other reasons for compactness, mechanical thickeners, clarifiers, and filters are used. The basis is the same as for Level B, except no pond is required.

Capital Costs

Thickener - 15 meter (50 ft.) diameter	=	$150,000
Filter system installed	=	35,000
Pumps, tanks, piping, collection	=	50,000
Conveyor	=	5,000
Building	=	5,000
Total		$245,000

At 10 yr life and 10% interest rate
Capital recovery factor = .1627
Annual investment costs = $39,862

Operating Costs

Solids wastes handling @ $0.30/ton	=	$26,400
Maintenance	=	20,000
Chemicals	=	20,000
Power	=	5,000
Labor	=	3,000
Taxes and insurance @ 2% of capital	=	5,000
Total		$79,400

Treatment Level E - Thickener and filter removal of suspended solids and recycle to eliminate discharge. The basis is the same as for Level D, complete recycle of treated wastes.

Capital Costs

The same as for Level D - pumping and piping to surface water discharge taken to be the same as for recycle piping and pumping.

Operating Costs

The same as for Level D
Total annual costs = $119,300

DRY GRINDING PLANTS

There are no discharges from this subcategory.

WET GRINDING PLANTS

Of the three facilities involved, one sends its small amount of waste water to nearby waste treatment facilities of much larger volume, the second has no waterborne waste due to the nature of its process and the third uses a settling pond to remove suspended solids prior to water recycle. Total costs for waste water treatment from this third operation are estimated as $2.60/kkg of wet ground mica produced ($2.30/ton). A capital investment of $65,000 is required.

BARITE

Of the twenty-seven known significant U.S. facilities producing barite ore or ground barite, nine facilities use dry grinding operations, fourteen use log washing and jigging methods to prepare the ore for grinding, and four use froth flotation techniques.

DRY GRINDING OPERATION

There is no water used in dry grinding facilities, therefore there are no treatment costs.

WASHING OPERATIONS

The ratio of barite product to wastes vary greatly with ore quality, but in all cases there is a large amount of solid waste for disposal. Only about 3 to 7 percent by weight of the ore is product. The remainder consists of rock and gravel, which are separated and recovered at the facility, and mud and clay tailings, which are sent as slurry to large settling and storage ponds.

In Missouri, where most of the washing operations are located, tailings ponds are commonly constructed by damming deep valleys. It is customary in log washing operations to build the initial pond by conventional earthmoving methods before the facility opens so that process water can be recycled. Afterwards the rock and gravel gangue are used by the facility to build up the dam on dikes to increase the pond capacity. This procedure provides a use for the gangue and also provides for storage of more clay and mud tailings. The clay and mud are used to seal the rock and gravel additions. All facilities totally recycle process water except during periods of heavy rainfall when intermittent discharges occur. A washing facility located in Nevada also uses tailings ponds with total recycle of waste water and no discharge at any time. The dry climate and the scarcity of water are the factors determining the feasibility of such operation. In Table 24 are estimated costs for treatment.

Operations in dry climates (e.g. Nevada) would be expected to have treatment costs similar to Level A, even at no discharge level. All facilities are currently at Level A or C. Some facilities use Level B treatment partially. The necessity and extent of such treatment depends on quality of water presently discharged. Level C is not achievable in unfavorable terrain. With favorable local terrain zero discharge of process water is achievable. Known ages range from less than 1 to 19 years. Age was not found to be a significant factor in cost variance. Both geographical

TABLE 24
BARITE (WET PROCESS) TREATMENT COSTS

PLANT SIZE 18,000 KKG PER YEAR OF Barite

PLANT AGE 11 YEARS PLANT LOCATION Missouri or Nevada

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		180,000	260,000	265,000		
ANNUAL CAPITAL RECOVERY		21,150	30,500	31,100		
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		10,000	16,400	13,600		
ANNUAL ENERGY AND POWER		10,000	10,000	11,000		
TOTAL ANNUAL COSTS $		41,150	56,900	55,700		
COST/ KKG Barite		2.26	3.13	3.06		
WASTE LOAD PARAMETERS (mg/liter)	RAW WASTE LOAD					
Suspended solids		15-327*	25*	0		
Iron		0.04-8.4*	1.0*	0		
Lead		0.03-2.0*	0.1*	0		
pH		6-9*	6-9*	-		

*only discharged during periods of heavy rainfall

LEVEL DESCRIPTION:

A. Complete recycle except in times of heavy rainfall

B . A plus treatment of all discharged water with lime and flocculants

C. Complete recycle - no discharge at all times (ability to achieve this level depends on local terrain - not all plants are capable of attaining zero discharge)

All costs are cumulative.

location and local terrain are significant factors in treatment costs. Western operations in dry climates can achieve no discharge at all times at a cost significantly below eastern operations. Costs vary significantly with local watersheds, elevations, and availability of suitable terrain for pond construction. Nine facilities in this subcategory have production rates ranging from 11,000 to 182,000 kkg/yr (12,100 to 200,000 tons/yr). The representative facility is 18,000 kkg/yr (20,000 tons/yr). Eight of the nine facilities have less than 30,000 kkg/yr production (33,000 tons/yr). The single large facility in this subcategory that was investigated is the western facility for which costs have been discussed earlier in this section. For the eight eastern facilities, the capital costs are estimated to be directly proportional to the 0.9 exponential of size over this range, and directly proportional for operating costs other than taxes, insurance and capital recovery.

Capital Costs

Pond cost, $/hectare ($/acre)		
(a) tailings ponds:	12,350	(5,000)
(b) clarification ponds:	7,400	(3,000)

Pond areas, hectares (acres)		
(a) tailings ponds:	8.1	(20)
(b) clarification ponds:	8.1	(20)

Pumps and pipes: $50,000

Operating and Maintenance Costs

Power unit cost:	$100/HP-yr
Pond maintenance:	2% of pond investment
Pump and piping maintenance:	6% of non-pond investment
Taxes and insurance:	2% of total investment
Flocculants:	$2.20/kg ($1.00/lb)
Lime:	$22/kkg ($20/ton)

FLOTATION OPERATIONS

Flotation is used on either beneficiated low grade ore or high-grade ore which is relatively free of sands, clays, and rocks. Therefore, they produce significantly less solid wastes (tailings) than washing operations, and consequently less cost for waste treatment.

Wastewater treatment is similar to that previously described for washing operations: pond settling and storage of tailings followed by recycle. Of the three facilities investigated in this category two are in the east and one in the west. The western facility achieves no discharge; the two eastern facilities do not.

Costs for the barite flotation process are given in Table 25. Level A is currently achieved in the Nevada facility. Levels B and C represent technology used by present eastern operations. Level D is for projected no discharge at eastern operations. At eastern operations ability and costs to achieve no discharge depend on local terrain. Costs developed are for cases where favorable terrain makes achievement of no discharge possible.

Ages for the three facilities ranged from 10 to 58 years. Age was not found to be a significant cost variance factor. Both geographical location and local terrain are significant cost variance factors. Western operations are able to achieve no discharge at treatment costs below those for intermittent discharge from eastern facilities. No known eastern facility currently achieves no discharge. The flotation facilities range from 33,600 to 91,000 kkg/yr (37,000 to 100,000 tons/yr). The representative facility is 70,000 kkg/yr (77,000 tons/yr). Treatment costs are essentially proportional to size in this range.

Capital Costs

Tailings pond cost, $/hectare ($/acre):	7,400	(3,000)
Pond area, hectares (acres):	20	(50)
Pumps and piping:	$50,000	
Chemical treatment facilities:	$50,000	

Operating and Maintenance Costs

Pond maintenance:	2% of pond investment
Taxes and insurance:	2% of total investment
Power - $100/HP-yr	
Treatment Chemicals	
Lime:	$22/kkg ($20/ton)
Flocculating agent:	$2.20/kg ($1/lb)

MINE DRAINAGE

The mining of barite is a dry operation and the only water normally involved is from pit or mine drainage resulting from rainfall and/or ground seepage. Most mines do not have any discharge. Rainwater in open pits is usually allowed to evaporate. One known mine, however, has over 1.9 x 10^6 l/day (0.5 mgd) of acidic ground seepage and rainwater runoff. Lime neutralization and pond settling of suspended solids of this mine drainage costs an approximate $2 per kkg of barite produced ($1.8/ton). Most of this cost is for lime and flocculating agents.

TABLE 25

BARITE (FLOTATION PROCESS) TREATMENT COSTS

PLANT SIZE 70,000 KKG PER YEAR OF Barite

PLANT AGE 33 YEARS PLANT LOCATION Missouri, Nevada, Georgia

		LEVEL				
		A (MIN)	B (min)	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		150,000	200,000	250,000	310,000	
ANNUAL CAPITAL RECOVERY		17,600	23,480	31,600	36,400	
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		6,000	7,000	12,000	11,400	
ANNUAL ENERGY AND POWER		10,000	15,000	15,000	15,000	
TOTAL ANNUAL COSTS $		33,600	45,480	58,600	62,800	
COST/ KKG Barite		0.49	0.67	0.86	0.92	
WASTE LOAD PARAMETERS (mg/liter)	RAW WASTE LOAD					
Suspended Solids	<50,000	0	3-250	25	0	
pH	-	-	6-9	6-9	-	

LEVEL DESCRIPTION:

A. Pond settling of solids plus recycle of water to process; no discharge (western operation)

B. Pond settling of solids plus recycle of water to process; intermittent discharge; no chemical treatment for discharged water

C. B plus chemical treatment with lime and/or flocculating agent to adjust pH and reduce suspended solids

D. B plus additional pond capacity for total impoundment (requires favorable local terrain)

FLUORSPAR

Beneficiation of mined fluorspar ore is accomplished by heavy media separations and/or flotation operations. Although these technologies are used separately in some instances, generally beneficiation facilities employ both techniques.

HEAVY MEDIA SEPARATIONS

The primary purpose of heavy media separations is to provide an upgraded and preconcentrated feed for flotation facilities. Five of the six heavy media operations have no waste water discharge. The sixth facility uses a pond to remove suspended solids then discharges to surface water. Wastewater treatment costs are given in Table 26. Level A technology is achieved by all facilities. Level B is currently achieved by 5 of the 6.

Ages for this subcategory range from 1 to 30 years. Age was not found to be a significant factor in cost variance. Facilities are located in the Illinois-Kentucky area and southwestern U.S. There are facilities with no process effluents in both locations. Location is not a significant factor in cost variance. The facilities having heavy media facilities range from 5,900 to 81,800 kkg/yr (6,500 to 90,000 tons/yr) production. The representative facility is 40,000 kkg/yr (45,000 tons/yr). Since thickeners are the major capital investment, capital costs are estimated to be directly proportional to the 0.7 exponential of size. Operating costs other than taxes, insurance and capital recovery are estimated to be directly proportional to size.

Capital Costs

Pond cost, $/hectare ($/acre): 7,400 (3,000)
Pond size, hectares (acres): 4 (10)
Pumps and piping costs: $20,000
Thickeners: $50,000

Operating and Maintenance Costs

Pond maintenance: 2% of pond investment
Pumps and piping maintenance: 6% of investment
Pond cleaning: 15,000 ton/yr @ $.35/ton
Power: $100/HP-yr

TABLE 26

FLUORSPAR (HMS PROCESS) TREATMENT COSTS

PLANT SIZE 40,000 KKG PER YEAR OF fluorspar

PLANT AGE 8 YEARS PLANT LOCATION Midwest

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $		50,000	70,000			
TOTAL						
ANNUAL CAPITAL RECOVERY		5,850	8,200			
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		7,050	8,250			
ANNUAL ENERGY AND POWER		2,500	5,000			
TOTAL ANNUAL COSTS $		15,400	21,450			
COST/ KKG fluorspar		0.38	0.52			
WASTE LOAD PARAMETERS (kg/ kkg of fluorspar)	RAW WASTE LOAD					
Suspended solids	340	0.13	0			
Dissolved Fluoride	0.04	0.04	0			
Lead	-	0.0002	0			
Zinc	-	0.0012	0			
pH	-	6-9	0			

LEVEL DESCRIPTION:

A. Spiral classifier followed by small pond with discharge

B. Thickener plus total recycle

All costs are cumulative.

FLOTATION SEPARATIONS

Wastewater from flotation processes are more difficult and costly to treat and dispose of than those from heavy media separation. The bulk of the solid wastes from the ore are discharged from the flotation process. Flotation chemicals probably interfere with settling of suspended solids and fluoride contents are higher than in the heavy media process.

Cost estimates for waste water treatment from a representative flotation facility are given in Table 27. Level A is typical of Kentucky-Illinois area waste water treatment. Level B represents costs for planned future treatment for these operations, Level C represents treatment technology used for municipal water, but not currently used for any fluorspar waste water.

In the fluorspar flotation category facility ages range from 1 to 35 years. Age has not been found to be a significant factor in cost variance of treatment options. Both geographical location and local terrain are significant cost variance factors. Dry climate western operations can achieve no discharge at lower costs than midwestern operations can meet normal suspended solids levels in their discharges. Facility sizes range from 13,600 to 63,600 kkg/yr (15,000 to 70,000 tons/yr). The representative facility size is 40,000 kkg/yr (45,000 tons/yr). The capital costs are estimated to be directly proportional to the 0.9 exponential of size over this range and directly proportional for operating costs other than taxes, insurance, and capital recovery.

Capital Costs

Pond cost, \$/hectare (\$/acre): 12,350 (5,000)
Pond size, hectares (acres): 10 (25)

Operating and Maintenance Costs

Labor: \$5.00/hr
Power: \$100/HP-yr
Taxes and insurance: 2% of investment
Flocculating chemicals: \$2.20/kg (\$1/lb)
Lime: \$22/kkg (\$20/ton)
Alum: \$55/kkg (\$50/ton)

TABLE 27

FLUORSPAR (FLOTATION PROCESS) TREATMENT COSTS

PLANT SIZE 40,000 KKG PER YEAR OF fluorspar

PLANT AGE 15 YEARS PLANT LOCATION Midwest

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		130,000	185,000	185,000		
ANNUAL CAPITAL RECOVERY		15,300	21,700	21,700		
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		24,600	53,700	69,700		
ANNUAL ENERGY AND POWER		8,000	10,000	10,000		
TOTAL ANNUAL COSTS $		47,900	85,400	101,400		
COST/ KKG of product		1.20	2.14	2.54		
WASTE LOAD PARAMETERS (kg/ KKG of product)	RAW WASTE LOAD					
Suspended solids	2,000	5-35	0.3-0.6	0.2-0.4		
Dissolved fluoride	0.05-0.2	0.05-0.2	0.05-0.2	0.05-0.1		

LEVEL DESCRIPTION:

A - pond settling and discharge

B - A plus treatment with flocculants

C - A plus alum treatment

All costs are cumulative.

FLUORSPAR DRYING AND PELLETIZING PLANTS

There are three significant fluorspar drying facilities. Two of these facilities are dry operations. The third has a wet scrubber but treats the effluent as part of HF production wastes. Pelletizing facilities are also dry operations.

MINE DRAINAGE

Fluorspar mines often have significant drainage. Normally the fluoride content is 3 mg/l or less and suspended solids are low. Even when higher concentrations of suspended solids are present, settling in ponds is reported to be rapid. Cost for removing these solids are estimated to be $0.01 to $0.05 per kkg or ton of fluorspar produced.

SALINES FROM BRINE LAKES

The extraction of several mineral products from lake brines is carried out at two major U.S. locations: Searles Lake in California and the Great Salt Lake in Nevada. Also lithium carbonate is extracted at Silver Peak, Nevada. The only wastes are depleted brines which are returned to the brine sources. There is no discharge of waste water and no treatment costs.

BORATES

The entire U.S. production of borax is carried out in the desert areas of California by two processes: the mining and extraction of borax ore and the trona process. The latter is covered in the section on salines from lake brines. The trona process has no waste water treatment or treatment costs since all residual brines are returned to the source. The mining and extraction process accounts for about three-fourths of the estimated U.S. production of borax. All waste water is evaporated in ponds at this facility. There is no discharge to surface water. Costs for the ponding treatment and disposal are given in Table 28. Since there is only one facility, minimum treatment and no discharge treatment costs are identical.

Capital Costs

Pond cost, $/hectare ($/acre): 20,000 (8,000)
Pond area, hectares (acres): 100 (250)
Pumps and piping: $500,000

Operating and Maintenance Costs

Pond maintenance: 2% of pond investment
Pump and piping maintenance: 6% of pump and piping investment
Power: $100/HP-yr
Taxes and insurance: 2% of total investment

TABLE 28
BORATES TREATMENT COSTS

PLANT SIZE 1,000,000 KKG PER YEAR OF Borates

PLANT AGE 17 YEARS PLANT LOCATION California

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		2,500,000				
ANNUAL CAPITAL RECOVERY		293,500				
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		120,000				
ANNUAL ENERGY AND POWER		30,000				
TOTAL ANNUAL COSTS $		443,500				
COST/ KKG Borates		0.44				
WASTE LOAD PARAMETERS (kg/ kkg of Borates)	RAW WASTE LOAD					
Solid wastes (insol.)	800	0				
Soluble wastes	2.5	0				

LEVEL DESCRIPTION:

A - evaporation of all wastewater in ponds.

All costs are cumulative.

POTASH

Potash is produced in four different locations by four different processes, all of which are in dry climate areas of the western U.S. Two processes, involving lake brines, have no waste water. All residual brines are returned to the lake. There are no treatment costs. The third process (Carlsbad Operations), dry mining followed by wet processing to separate potash from sodium chloride and other wastes, utilizes evaporation ponds for attaining no discharge or waste water. Treatment costs are given in Table 29. The fourth process (Moab Operations) involves solution mining followed by wet separations. This process also has no discharge of waste water. Treatment costs are given in Table 30.

Age is not a cost variance factor. All facilities are located in dry western geographical locations. Location is not a significant factor on costs. Known facility sizes range from 450,000 to 665,000 kkg/yr (500,000 to 730,000 tons/yr) for Carlsbad Operations. There is only one facility in the Moab Operations category. There is no significant cost variance factor with size for the Moab or Carlsbad Operations subcategories.

Cost Basis for Table 29

Capital Costs

Pond cost, $/hectare ($/acre): 2,470 (1,000)
Evaporation pond area, hectares (acres): 121 (300)
Pumps and piping: $100,000

Operating and Maintenance Costs

Maintenance, taxes and insurance: 4% of investment
Power: $100/HP-yr

Cost Basis for Table 30

Capital Costs

Dam for canyon: $100,000
Pumps and piping: $250,000

Operating and Maintenance Costs

Labor: $10,000
Maintenance: 8% of investment
Taxes and insurance: 2% of investment
Power: $100/HP-yr

TABLE 29

POTASH (CARLSBAD OPERATIONS) TREATMENT COSTS

PLANT SIZE 500,000 KKG PER YEAR OF Potash

PLANT AGE 30 YEARS PLANT LOCATION New Mexico

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		400,000				
ANNUAL CAPITAL RECOVERY		47,000				
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)						
ANNUAL ENERGY AND POWER		8,000				
TOTAL ANNUAL COSTS $		71,000				
COST/ KKG Potash		0.14				
WASTE LOAD PARAMETERS (kg/ kkg of Potash)	RAW WASTE LOAD					
Sodium chloride	0-3750	0				
Clays	15-235	0				
Magnesium sulfate	0-640	0				
Potassium sulfate	0-440	0				
Potassium chloride*	0-318	0				

*as brine

LEVEL DESCRIPTION:

A - Evaporation ponds

All costs are cumulative.

TABLE 30

POTASH (MOAB OPERATIONS) TREATMENT COSTS

PLANT SIZE 200,000 KKG PER YEAR OF Potash

PLANT AGE 10 YEARS PLANT LOCATION Utah

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		350,000				
ANNUAL CAPITAL RECOVERY		56,950				
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		45,000				
ANNUAL ENERGY AND POWER		5,000				
TOTAL ANNUAL COSTS $		106,950				
COST/ KKG potash		0.53				
WASTE LOAD PARAMETERS (kg/ kkg of potash)	RAW WASTE LOAD					
Sodium chloride	640	0				

LEVEL DESCRIPTION:

All costs are cumulative.

A - Holding pond plus on-land evaporation

TRONA

All U.S. mining of trona ore is in the vicinity of Green River, Wyoming. There are four mining facilities, three of which also process ore to pure sodium carbonate (soda ash). The fourth facility has only mining operations at this time. Wastewater from these operations come from mine drainage, ground water and process water.

PROCESS WATER

Of the three processing facilities, two have no discharge of process water and one does. Plans are under way at this one facility to eliminate process water discharge. Table 31 gives cost estimates for both treatment levels for the hypothetical representative facility.

The ages of the three processing facilities range from 6 to 27 years. Age was not found to be a significant factor in cost variance. All facilities are located in sparsely populated areas close to Green River, Wyoming. Geographical location is not a significant cost variance factor. Local terrain variations are a factor. Some desired or existing pond locations give seepage and percolation problems; others do not. The costs to control seepage or percolation in an area with unfavorable underlying strata can be considerably more than the original installation cost of a pond in an area with no seepage problems. The costs are valid for locations with minor pond seepage problems, which at present is the typical case. For locations with bad seepage problems, the costs of an interceptor trench to an impermeable strata plus back-pumping should be added. Based on 1973 soda ash production figures, the three processing facilities are approximately of the same size. All of these facilities are substantially increasing their output over a period of time. Size is not a significant factor in cost variance from facility-to-facility.

Capital Costs

Pond cost, \$/hectare (\$/acre): 7,400 (3,000)
Pond area, hectares (acres)
    Level A: 162 (400)
    Level B: 271 (670)
Pumps and piping
    Level A: \$300,000
    Level B: \$400,000

TABLE 31

TRONA TREATMENT COSTS

PLANT SIZE 1,000,000 KKG PER YEAR OF Soda Ash

PLANT AGE 15 YEARS PLANT LOCATION Wyoming

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		1,500,000	2,400,000			
ANNUAL CAPITAL RECOVERY		176,100	282,100			
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		102,000	160,000			
ANNUAL ENERGY AND POWER		80,000	100,000			
TOTAL ANNUAL COSTS $		358,100	542,000			
COST/ KKG soda ash		0.36	0.54			
WASTE LOAD PARAMETERS (kg/ kkg of soda ash)	RAW WASTE LOAD					
Suspended Solids	5	0.005	0			
Dissolved Solids	35	0.06	0			

LEVEL DESCRIPTION:

All costs are cumulative.

A — Evaporation ponds with small discharge
B — Evaporation ponds with no discharge

Operating and Maintenance Costs

Pond maintenance: 2% of pond investment
Pump and piping maintenance: 6% of pond investment
Taxes and insurance: 4% of total investment
Power: $100/HP-yr

MINE DRAINAGE

All of the four mines have some drainage. The average flow mines is 0.64 x 10^6 l/day (0.17 mgd). This is approximately 10 percent of average process water and is estimated on this basis to cost $0.01 to $0.05 per kkg or ton of soda ash produced for ponding and evaporative treatment. One facility currently has an unusually high mine pumpout volume, 1.8 x 10^6 l/day (0.43 mgd). The costs to contain and evaporate this amount are proportionately higher.

GROUND WATER AND RUNOFF WATER

Ground water and runoff water are also led to collection ponds where settling and substantial evaporation take place. On the basis of known information no meaningful cost estimate can be made, since the amounts are extremely variable and, nevertheless, small compared to the process water volume.

SODIUM SULFATE

Sodium sulfate is produced from natural sources in three different geographical areas by three different processes:

(1) Recovery from the Great Salt Lake;
(2) Recovery from Searles Lake brines;
(3) Recovery from west Texas brines.

Processes (1) and (2) have no waste water treatment or treatment costs. All residual brines are returned to the lakes. Process (3) has waste water which is percolated and evaporated in existing mud flat lakes. There is no treatment. The waste water flows to the mud lake by gravity. Costs are almost negligible (estimated as \$0.01 to \$0.05 per kkg or ton of sodium sulfate produced).

ROCK SALT

This study covers those facilities primarily engaged in mining, crushing and screening rock salt. Some of these facilities also have evaporation operations with a common effluent. The waste water from mining, crushing and screening operations consists primarily of a solution of varying sodium chloride content which comes from one or more of the following sources:

(1) wet dust collection in the screening and sizing step;
(2) washdown of miscellaneous spills in the operating area and dissolving of the non-saleable fines;
(3) seepage from mine shafts.
(4) runoff from salt piles

Wastewater volumes are usually fairly small, less than 500,000 l/day (130,000 gal/day), and are handled in various ways, including well injection and surface disposal. Well injection costs for minewater drainage are estimated to be in the range of $0.01 to $0.05 per kkg or short ton of salt produced. Surface disposal is costed in Table 32. Most often there is no treatment of the miscellaneous saline waste water associated with this subcategory. Some facilities use settling ponds to remove suspended solids prior to discharge. In the event that land is not available for ponds, costs for alternate technology using clarifiers instead of ponds are given in Level C. Age, location, and size are not significant factors in cost variance.

Capital Costs

Pond cost, $/hectare ($/acre): 49,000 (20,000)
Pond size, hectares (acres): 0.2 (0.5)
Pumps and piping cost: $5,000
Clarifier: $35,000

Operating and Maintenance

Pond maintenance: 2% of pond investment
Pump and piping maintenance: 10% of pump and piping investment
Power: $100/HP-yr
Taxes and insurance: 2% of total investment.

For alternative D, an actively used storage silo of 100,000 tons capacity is assumed.

TABLE 32
ROCK SALT TREATMENT COSTS

PLANT SIZE 1,000,000 KKG PER YEAR OF salt

PLANT AGE 30 YEARS PLANT LOCATION Eastern United States

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		0	15,000	50,000	523,000	
ANNUAL CAPITAL RECOVERY		0	1,760	8,150	85,300	
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		0	700	3,000	23,000	
ANNUAL ENERGY AND POWER		0	500	3,000	2,000	
TOTAL ANNUAL COSTS $		0	2,960	13,150	110,300	
COST/ KKG salt		0	<0.01	0.01	11	
WASTE LOAD PARAMETERS (kg/ kkg of salt)	RAW WASTE LOAD					
Suspended solids	0-0.9	0-0.9	0.009	0.009		
Dissolved solids					0	

All costs are cumulative.

LEVEL DESCRIPTION:

A — No wastewater treatment
B — Pond settling of suspended solids followed by discharge
C — Clarifier removal of suspended solids followed by discharge
D- Salt storage pile structures

PHOSPHATE ROCK

Phosphate ore is mined in four different regions of the U.S.:

Florida:	78% of production
North Carolina:	5% of production
Tennesse:	5% of production
Western States:	12% of production

For purposes of costs the above production may be separated into two groups: eastern operations and western operations.

EASTERN OPERATIONS

The beneficiation of phosphate ore involves large volumes of waste water. In addition, there are large quantities of solid wastes. Raw wastes, sand, and small particle sized slimes in the process raw wastes exceed the quantity of phosphate product. Essentially two waste water streams come from the process: sand tailings stream and a slimes stream. The sand tailings settle rapidly for use in land reclamation. The water from this stream can then be recycled. Slimes, on the other hand, settle fairly rapidly but only compact to 10-20 percent solids. This mud ties up massive volumes of water in large retention ponds. Most of the process waste water treatment costs are also tied up in the construction of massive dams and dikes around these ponds. All mine and beneficiating facilities practice complex water control and reuse. The extent of control and reuse depends on many factors, including:

(1) topography
(2) mine-beneficiating facility waste pond layouts
(3) age of facilities
(4) fresh water availability
(5) regulations
(6) level of technology employed
(7) cost.

Most water discharges are intermittent; heavy during the wet season (3-6 months/yr), slight or non-existent during dry seasons (6-9 months/yr). Water discharged during the wet season due to insufficient storage capacity could be used during the dry season, if enough empty pond space is available.

Since water control fundamentally involves storage and transport (pumping) operations, by construction of additional storage pond and piping and pumping facilities almost any degree of process waste water control may be achieved up to and including closed cycle. No discharge of process water involves two premises:

(1) Only process water is contained. Mine drainage is isolated and used as feed water or treated (if needed) and discharged separately. Rainwater runoff is also treated separately, if needed.

(2) Evaporation-rainfall imbalances are more than counterbalanced by water losses in slime ponds. Slime ponds are essentially water accumulation ponds where water is removed from recycle by holdup in the slimes.

All costs are for treatment and storage of suspended solids. There is no treatment applied specifically for fluorides or phosphates although existing treatment will result in a degree of removal of these pollutants. Table 33 gives costs for three levels of treatment technology. All facilities use Level A technology, and most use some degree of Level B technology. Level C technology is currently not used. All discharged wastes are expressed in concentrations, since the volume of waste water discharges from the facilities vary widely depending on age, terrain, local rainfall, and water control practice. Most facilities currently achieve less than 30 mg/l suspended solids as a monthly average at Level A. Those that do not would be expected to have the additional expenditures of Level B to reach 30 mg/l suspended solids.

Facilities representing the eastern phosphate rock subcategory range in age from 3 to 37 years. Age was not found to be significant factor in cost variance. Operations are located in Florida, North Carolina and Tennessee. Pond construction is different in Tennessee, which is hilly, than in flat areas such as Florida and North Carolina. Flat area facilities have diked ponds while in Tennessee facilities use dammed valleys. A comparison indicates that construction costs are approximately the same for both areas and location is not a significant factor in cost variance. The facilities in the eastern grouping range in size from 46,300 to 4,090,000 kkg/yr (51,000 to 4,500,000 tons/yr). The representative facility is 2,000,000 kkg/yr (2,200,000 tons/yr). Capital costs are estimated to be directly proportional to the 0.9 exponent of size and directly proportional for operating costs other than taxes, insurance and capital recovery.

TABLE 33

PHOSPHATE ROCK (EASTERN) TREATMENT COSTS

PLANT SIZE 2,000,000 KKG PER YEAR OF product

PLANT AGE 15 YEARS PLANT LOCATION Florida-North Carolina-Tennessee

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		8,000,000	8,650,000	12,000,000		
ANNUAL CAPITAL RECOVERY		804,000	910,000	1,560,000		
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		360,000	389,000	429,000		
ANNUAL ENERGY AND POWER		240,000	300,000	335,000		
TOTAL ANNUAL COSTS $		1,404,000	1,599,000	2,324,000		
COST/ KKG product		0.70	0.80	1.16		
WASTE LOAD PARAMETERS (mg/liter)	RAW WASTE LOAD --					
Suspended Solids		3-560	<30	0		
Dissolved Fluoride		2*	2*	0		
Phosphorus (total)		4*	4*	0		

*Estimated average values.

LEVEL DESCRIPTION:

A — Pond treatment of slimes and sand tailings
B — A plus improved process water segregation
C — Pond treatment plus impoundment of all process water
All costs are cumulative.

Capital Costs

Pond cost, \$/hectare (\$/acre): 17,300 (7,000)
Pond area, hectares (acres): 400 (1,000)
Pumps and piping: \$1,000,000

Operating and Maintenance Costs

Labor and maintenance: 2.5% of total investment
Taxes and insurance: 2% of total investment
Power: \$100/HR-yr

WESTERN OPERATIONS

Because of the favorable rainfall-evaporation balance existing for western phosphate mines and processing facilities, all facilities are either at the no discharge level or can be brought to this level. Of six operating areas, five have no discharge. Table 34 gives cost of waste water treatment technology for western operations.

The six western operations range in age from 6 to 27 years. Age was not found to be a significant cost variance factor. All facilities in this subcategory are located in Idaho, Wyoming and Utah. Location is not a significant cost variance factor. Facilities in this subcategory range in size from 296,000 to 909,000 kkg/yr (326,000 to 1,000,000 tons/yr). The representative facility is 500,000 kkg/yr (550,000 tons/yr). Over this range of sizes, capital costs can be estimated to be directly proportional to the exponent of 0.9 to size, and operating costs other than capital recovery, taxes and insurance are approximately directly proportional to size.

Capital Costs

Pond costs, \$/hectare (\$/acre): 4,900 (2,000)
Pond size , hectares (acres): 100 (250)
Thickener: \$200,000
Pumps and piping: \$150,000

Operating and Maintenance Costs

Labor and maintenance: 2.5% of investment
Power: \$100/HP-yr
Taxes and insurance: 2% of investment

TABLE 34

PHOSPHATE ROCK (WESTERN) TREATMENT COSTS

PLANT SIZE 500,000 KKG PER YEAR OF product

PLANT AGE 10 YEARS PLANT LOCATION Idaho-Utah

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		850,000	1,250,000			
ANNUAL CAPITAL RECOVERY		93,500	140,500			
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		38,500	56,500			
ANNUAL ENERGY AND POWER		50,000	75,000			
TOTAL ANNUAL COSTS $		182,000	272,000			
COST/ KKG product		0.36	0.54			
WASTE LOAD PARAMETERS (kg/ kkg of product)	RAW WASTE LOAD					
Suspended solids	1700	<0.05	0			
Fluoride (as ion)	-	<0.001	0			
Phosphorus (total)	-	<0.001	0			

LEVEL DESCRIPTION:

A — Thickener plus evaporation ponds; discharge of residual to surface water

B — Level A plus additional evaporation ponds to give no discharge.

All costs are cumulative.

MINE DRAINAGE

The high water table plus the heavy seasonal rainfall in most of the eastern mining areas usually causes the mining pits to collect water. Whenever feasible, mine drainage is used for slurrying phosphate matrix to the beneficiation process. When this is not possible, drainage can be pumped into other mined out pits. Mine drainage involves primarily on-property water control. Any that is may be expected to be treated as waste water. Treatment costs are roughly estimated at $0.01 to $0.05 per kkg or ton of product.

SULFUR (FRASCH PROCESS)

There are two subcategories of sulfur mining:

(1) anhydrite deposit mining;
(2) on-shore salt dome mining;

ANHYDRITE DEPOSIT MINING

The following is a comparison of waste water from mining of sulfur from anhydrite deposits to that from mining of salt dome deposits:

(1) The porous structure of anhydrite deposits absorbs more of the injected water and reduces the amount of bleedwater.

(2) Since the anhydrite deposits are not filled with salt, bleedwater is lower in dissolved solids than the average for salt dome bleedwater. Anhydrite mines recycle this bleedwater to the formation.

(3) The location of anhydrite mines is in western Texas where the dry climate makes it possible to evaporate waste water. Salt dome mines are in Louisiana and east Texas which have more rainfall.

Treatment and cost options are developed in Table 35 for complete recycle of anhydrite deposit mining bleedwater. Since both anhydrite deposit mines are now accomplishing this level, the costs also represent minimum level treatment technology. Most of the costs are for water treatment chemicals for the recycled bleedwater.

The anhydrite deposit mining subcategory consists of two facilities, 5 and 7 years of age. Age is not a significant cost variance factor. Both facilities are located in western Texas. Location is therefore not a significant cost variance factor. Based on water treatment costs supplied by both facilities, size in existing facilities is not a significant cost variance factor.

Capital Costs

Water treatment installations:	$300,000
Thickeners and evaporation ponds:	$100,000
Pumps and piping:	$150,000

TABLE 35

SULFUR (ANHYDRITE) TREATMENT COSTS

PLANT SIZE 1,000,000 KKG PER YEAR OF sulfur

PLANT AGE 6 YEARS PLANT LOCATION Western Texas

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		550,000				
ANNUAL CAPITAL RECOVERY		90,000				
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		705,000				
ANNUAL ENERGY AND POWER		30,000				
TOTAL ANNUAL COSTS $		825,000				
COST/ KKG sulfur		0.83				
WASTE LOAD PARAMETERS (kg/ kkg of sulfur)	RAW WASTE LOAD					
Water softener sludge	12.5					
Suspended solids	-	0				
Dissolved solids	21.3- 43.2	0				

LEVEL DESCRIPTION:

A — Recycle of all bleedwater, use of on-site evaporative disposal of water softener sludges.

All costs are cumulative.

Operating and Maintenance Costs

Bleedwater volume, l/day (mgd): 18.9 x 10^6 (5.0)
Bleedwater treatment, $/1,000 liters (gallons): $0.09 ($0.35)
The energy and power costs were supplied by facility 2020

ON-SHORE SALT DOME MINING

There are nine facilities in the U.S. producing sulfur from on-shore salt dome operations. The wide variability of bleedwater quantity per ton of sulfur produced has been taken into account by expressing all pollutants in terms of concentration rather than weight units. Cost analyses for on-shore salt dome sulfur facilities are given in Table 36. Several companies are using (or have used) Level A technology, at least one uses Level B as part of their treatment, one uses Level C, five use Level D, one uses Level E, one Level F and no one currently uses Level G. Level G is included to show the costs for complete oxidation of all sulfides, in the bleedwater to sulfates.

The on-shore salt dome sulfur mining subcategory consists of 9 facilities ranging in age from 6 to 45 years. Age is not a significant cost variance factor. All facilities are located in eastern Texas and Louisiana. Geographical location is a significant cost variance factor only in that lengthy ditches (up to 37 km or 22 miles) often had to be dug to get the bleedwater discharge to suitable surface water. All facilities now have such outlets. New facilities in this subcategory would have to make such provisions, quite likely at major expense. The nine facilities in this subcategory range from 150,000 to 1,270,000 kkg/yr (165,000 to 1,400,000 tons/yr). The representative facility is 500,000 kkg/yr (550,000 tons/yr). The capital costs over this size range are estimated to be directly proportional to the 0.8 exponential of size for process equipment treatment facilities such as Levels C and F, 0.9 exponential for mixed facilities such as Level E and directly proportional to size for Level D pond treatment. Operating costs other than taxes, insurance and capital recovery are estimated to be directly proportional to size.

The costs are assumed to be directly proportional to the bleedwater volume per unit of production. Exclusive of sea water dilution, the range of relative bleedwater volumes found was 6,900 to 22,100 l/kkg (1,700 to 5,300 gal/ton).

Capital costs for Levels C through F were taken from industry supplied values and adjusted for size. Level G is based on 500 mg/l of sulfides in 18.9 x 10^6 l/day (5 mgd of bleedwater). Operating and maintenance costs for Levels C

TABLE 36

SULFUR (ON-SHORE SALT DOME) TREATMENT COSTS

PLANT SIZE 500,000 KKG PER YEAR OF sulfur

PLANT AGE 26 YEARS PLANT LOCATION Louisiana-East Texas

		LEVEL						
		A (MIN)	B	C	D	E	F	G
INVESTED CAPITAL COSTS: $								
TOTAL		50,000	50,000	1,540,000	3,200,000	1,500,000	3,000,000	20,000
ANNUAL CAPITAL RECOVERY		5,870	5,870	250,000	375,700	176,000	488,000	3,200
OPERATING AND MAINTENANCE COSTS: $								
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		2,500	5,000	145,000	102,000	300,000	415,000	3,400,000
ANNUAL ENERGY AND POWER		1,000	20,000	10,000	10,000	100,000	25,000	1,000
TOTAL ANNUAL COSTS $		9,370	30,870	405,500	488,400	570,000	928,000	3,404,000
COST/ KKG sulfur		0.02	0.06	0.81	0.98	1.15	1.86	6.80
WASTE LOAD PARAMETERS	RAW WASTE LOAD							
Sulfide, mg/liter	600–1000	500	200–400	< 1	< 1	< 1	< 1	0
Suspended solids, mg/liter	< 50	< 50	< 50	< 50	< 50	< 50	30	< 50

LEVEL DESCRIPTION:

A — Flashing of hydrogen sulfide from bleedwater
B — Spray aeration
C — Flue gas stripping reaction plus ponding
D — Large oxidation and settling ponds
E — Aeration in small ponds followed by mixing of partially treated bleedwater with 10-20 times its volume of oxygen-containing water
F — Chemical treatment with sulfurous acid
G — Chemical treatment with chlorine

through F were taken from industry supplied values. The chlorine costs for Level G are $110/kkg ($100/ton).

OFF-SHORE SALT DOME MINING

There is only one operational off-shore salt dome facility. Bleedwater is directly discharged without treatment into the Gulf of Mexico. Dissolved methane gas occurring naturally in the bleedwater provides initial turbulent mixing of bleedwater and sea water. Dissolved oxygen in the sea water reacts with the sulfides present. Current practice and two additional treatment technologies and their estimated costs are given in Table 37. Level A represents present technology; Level B is piping of all bleedwater to shore (10 miles away) followed by on-shore ponding treatment; Level C is off-shore chemical treatment of sulfides with chlorine. Level B is predicated on right-of-way and land availability, which has yet to be established, for pipeline and pond construction. Level C technology is not currently utilized in any existing sulfur production facility.

Capital Costs

Pumps and piping:	$10,200,000
Land cost, $/hectare ($/acre):	12,300 (50,000)
Land area, hectares (acres):	40 (100)
Pond cost, $/hectare, ($/acre):	6,200 (2,500)
Dilution pumping station:	$520,000
New off-shore platforms:	$4,200,000
Pumps and piping:	$2,200,000
Chemical treatment facilities:	$200,000
Construction overhead:	20% of direct costs

Operating and Maintenance Costs

Labor and maintenance:	8% of investment
Power:	$100/HP-hr
Chlorine, dollars/kkg (dollars/ton):	110 (100)
Taxes and insurance:	2% of investment costs

TABLE 37

SULFUR (OFF-SHORE SALT DOME) TREATMENT COSTS

PLANT SIZE 1,000,000 KKG PER YEAR OF sulfur

PLANT AGE 14 YEARS PLANT LOCATION Off-Shore Louisiana

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		0	13,750,000	7,920,000		
ANNUAL CAPITAL RECOVERY		0	2,237,000	1,288,600		
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		0	1,385,000	6,212,000		
ANNUAL ENERGY AND POWER		0	200,000	100,000		
TOTAL ANNUAL COSTS $		0	3,822,000	7,600,600		
COST/ KKG sulfur		0	3.82	7.60		
WASTE LOAD PARAMETERS (kg/ kkg of sulfur)	RAW WASTE LOAD					
Suspended Solids	0.3	0.3	0.2	0.2		
Sulfides	5.5	5.5	0.03	0.03		

LEVEL DESCRIPTION:

A — Use of oxygen in seawater to oxidize sulfides

B — All bleedwater pumped to shore followed by on-shore ponding and mixing with ambient water to oxidize sulfides

C — Off-shore chemical oxidation of sulfides with chlorine

All costs are cumulative.

MINERAL PIGMENTS (IRON OXIDE PIGMENTS)

One of two processes are used depending on the source and purity of the ore. For relatively pure ores, processing consists simply of crushing and grinding followed by air classification. This is a dry process which uses no water and has no treatment costs. Alternatively, for less pure ores, a washing step designed to remove sand and gravel, followed by dewatering and drying is used. This process has waste water treatment costs. Table 38 gives cost estimates for waste water treatment for this wet process.

The one facility found using the wet process has an age of 50 years. Age is not believed to be a significant factor for cost variance. Location was not found to be a significant factor for cost variance. Only one facility was found using the wet process. Size is not believed to be a significant factor for cost variance.

Capital Costs

Pond cost, $/hectare ($/acre): 24,700 (10,000)
Settling pond area, hectares (acres): 0.40 (1)
Pumps and piping: $5,000

Operating and Maintenance Costs

Maintenance: 4% of investment
Power: $100/HP-yr
Taxes and insurance: 2% of investment

TABLE 38

MINERAL PIGMENTS TREATMENT COSTS

PLANT SIZE 3,000 KKG PER YEAR OF product

PLANT AGE 50 YEARS PLANT LOCATION Eastern United States

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		15,000	20,000			
ANNUAL CAPITAL RECOVERY		1,750	2,530			
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		900	1,200			
ANNUAL ENERGY AND POWER		500	1,000			
TOTAL ANNUAL COSTS $		3,250	4,550			
COST/ KKG product		1.08	1.52			
WASTE LOAD PARAMETERS (kg/ kkg of product)	RAW WASTE LOAD					
Suspended Solids	--	2.3	0			

LEVEL DESCRIPTION:

A — Pond settling and discharge

B — Pond settling and total recycle

All costs are cumulative.

LITHIUM MINERALS

There are only two facilities mining and processing spodumene ore in the U.S. At both facilities the process water recycle is 90 percent or greater. The remainder is discharged. Large volumes of solid wastes are inherent to the process. These wastes are stored and/or disposed of by a combination of the following means:

(1) Landfill or land storage of solids;
(2) Storage of settled solids in ponds;
(3) Processing and recovery as salable by-products; and
(4) A small portion is discharged to surface water as suspended or dissolved materials.

The two facilities differ as to the above options employed. Processing and recovery or by-products also introduces new wastes into the waste water that are not present otherwise. Therefore, the treatment technologies and costs developed in Table 39 represent the best estimate of composite values for both facilities. Level A represents present performance and Level B future performance. Level B is based mainly on projected installations for which the two facilities have supplied technology and cost information. Age was not found to be a significant factor in cost variance. Both facilities are located in North Carolina.

Capital Costs

Pond costs, $/hectare ($/acre): 7,400 (3,000)
Pond area, hectares (acres): 50 (125)
Pumps and piping: $100,000

Operating and Maintenance Costs

Pond maintenance: 2% of invested pond capital
Non-pond maintenance: 6% of invested non-pond capital
Labor cost: $10,000/man-yr
Power: $100/HP-yr
Chemical: $100,000/yr

MINE DRAINAGE

Mine drainage is less than 10 percent of the total waste water volume and is now partially treated with the process waste water. Approximate estimates for treating any necessary residual mine drainage water are $0.01 to 0.05/kkg of product produced.

TABLE 39
LITHIUM MINERALS TREATMENT COSTS

PLANT AGE 15 YEARS PLANT LOCATION North Carolina

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		475,000	725,000			
ANNUAL CAPITAL RECOVERY		77,300	128,000			
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		133,000	212,000			
ANNUAL ENERGY AND POWER		10,000	15,000			
TOTAL ANNUAL COSTS $		220,300	340,000			
COST/ KKG spodumene concentrate		4.90	7.56			
WASTE LOAD PARAMETERS (kg/ kkg of spodumene concentrate)	RAW WASTE LOAD					
Suspended Solids	100-620	0.9	0.9			

LEVEL DESCRIPTION:

A — Ponding of wastewater to remove suspended solids plus recycle of process wastewater

B — Level A plus segregation and treatment of additional wastewater streams plus recycle of all process wastewater

All costs are cumulative.

BENTONITE

There is no waste water from the processing of bentonite. Therefore, there is no treatment cost involved.

FIRE CLAY

The only waste water from mining and processing of fire clay is mine water discharge. Treatment costs for settling suspended solids in mine water are estimated at $0.01-0.05/kkg of produced fire clay for non-acid mine drainage. Since there is no process water discharge in the production of fire clay, there are no costs for process waste water treatment.

FULLER'S EARTH

Fuller's earth was divided into two subcategories - attapulgite and montmorillonite. Suspended solids in attapulgite mine drainage and process water generally settle rapidly. Suspended solids in montmorillonite mine drainage and process water are more difficult to settle. Estimates of treatment costs for mine water, including use of flocculating agents to settle montmorillonite wastes, range from $0.17 to $0.28/kkg of montmorillonite produced, see Table 42. Process and air scrubber waste water treatment costs are summarized in Tables 40 and 41.

In the montmorillonite subcategory, there are three facilities ranging in age from 3 to 18 years. Age is not a significant factor in cost variance. There are four facilities representing the attapulgite subcategory ranging in age from 20 to 90 years. Age is not a significant factor in cost variance.

The facilities in the montmorillonite subcategory range from 13,600 to 207,000 kg/yr (15,000-228,000 ton/yr). The representative facility is 182,000 kkg/yr (200,000 ton/yr). The attapulgite facilities range from 21,800 kkg/yr (24,000 ton/yr) and 227,000 kkg/yr (250,000 ton/yr). The representative facility is 200,000 kkg/yr (220,000 ton/yr). In both these subcategories the capital costs are estimated to be directly proportional to the 0.9 exponential of size and directly proportional for operating costs other than taxes, insurance and capital recovery.

Cost Basis for Table 40

Capital Costs
    Pond cost, $/hectare ($/acre): 24,700 (10,000)
    Mine pumpout settling pond area, hectares (acres):0.1 (0.25)

TABLE 40

ATTAPULGITE TREATMENT COSTS

PLANT SIZE 200,000 KKG PER YEAR OF Attapulgite

PLANT AGE 60 YEARS PLANT LOCATION Georgia-North Florida Region

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		71,000	77,000	95,000		
ANNUAL CAPITAL RECOVERY		8,400	9,300	11,100		
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		37,400	39,800	39,100		
ANNUAL ENERGY AND POWER		200	200	300		
TOTAL ANNUAL COSTS $		46,000	49,300	50,500		
COST/ KKG		0.21	0.22	0.23		
WASTE LOAD PARAMETERS kg/ kkg	RAW WASTE LOAD					
TSS		0.01-0.02	0.01	0		
pH		6-9	6-9	-		

All costs are cumulative.

LEVEL DESCRIPTION:

A — pond settling
B — A plus flocculating agents
C — B plus recycle to process

TABLE 41

MONTMORILLONITE TREATMENT COSTS

PLANT SIZE 182,000 KKG PER YEAR OF Montmorillonite

PLANT AGE 10 YEARS PLANT LOCATION Georgia

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		60,000	65,000	80,000		
ANNUAL CAPITAL RECOVERY		7,000	7,900	9,400		
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		30,900	32,900	32,300		
ANNUAL ENERGY AND POWER		200	200	300		
TOTAL ANNUAL COSTS $		38,100	41,000	43,000		
COST/ KKG Montomorillonit		0.21	0.22	0.24		
WASTE LOAD PARAMETERS (kg/kkg of montmorillonite)	RAW WASTE LOAD					
TSS		0.3	0.05	0		
pH		6-9	6-9	-		

LEVEL DESCRIPTION:

All costs are cumulative.

A — pond settling of scrubber water
B — A plus flocculating agents
C — B plus recycle to process

TABLE 42

MONTMORILLONITE MINE WATER TREATMENT COSTS

PLANT SIZE 182,000 KKG PER YEAR OF Montmorillonite

PLANT AGE 10 YEARS PLANT LOCATION Georgia

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		0	60,000	62,000		
ANNUAL CAPITAL RECOVERY		0	15,800	16,300		
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		0	12,300	32,300		
ANNUAL ENERGY AND POWER		0	3,000	3,000		
TOTAL ANNUAL COSTS $		0	32,300	51,800		
COST/ KKG Montmorillonite		0	0.17	0.28		
WASTE LOAD PARAMETERS	RAW WASTE LOAD					
TSS, mg/liter		200—5,000	200—2,000	<50		

LEVEL DESCRIPTION:

All costs are cumulative.

A — no treatment
B — pond settling
C — B plus flocculating agents

Process Settling pond area, hectares (acres):2 (5)
Pumps and pipes: $10,000

Operating and Maintenance Costs
Energy unit cost: $0.01/kwh
Labor rate assumed: $10,000/yr

Cost Basis for Table 41

Capital Costs
Pond cost, $/hectare ($/acre):24,700 (10,000)
Mine pumpout settling pond hectares (acres):0.1 (0.25)
Process settling pond area, hectares (acres):2 (5)
Pumps and pipes: $10,000

Operating and Maintenance Costs
Treatment chemicals
Flocculating agent: $1.50/kg ($0.70/lb)
Energy unit cost: $0.01/kwh
Labor rate assumed: $10,000/yr

KAOLIN

Kaolin mining and processing operations differ widely as to their waste water effluents. All treatments involve settling ponds for their basic technology. Dry mines need no treatment or treatment expenditures. Wet mines (from rain water and ground seepage) use settling ponds to reduce suspended solids. These settling ponds are small and cost an estimated $0.01-$0.06/kkg of clay product.

Processing facilities may be either wet or dry. Dry facilities have no treatment or treatment costs. Wet processing facilities have process waste water from two primary sources: scrubber water from air pollution facilities, and process water that may contain zinc compounds from a product bleaching operation. Scrubber and process water need to be treated to reduce suspended solids and zinc compounds. Costs for reduction are summarized in Table 43 for wet process kaolin.

The kaolin wet process subcategory consists of two facilities having ages of 29 and 37 years. Age is not a cost variance factor. The wet process kaolin operations are only located in Georgia, hence not a variance. The two wet process kaolin facilities are 300,000 and 600,000 kkg/yr (330,000 and 650,000 ton/yr) size. The representative facility is 450,000 kkg/yr (500,000 ton/yr). Capital costs over this size range are estimated to be directly proportional to the 0.9 exponential of size, and operating costs other than taxes, insurance, and capital recovery are estimated to be directly proportional to size.

Capital Costs
- Pond cost, $/hectare ($/acre): 12,350 (5,000)
- Settling pond area, hectares (acres): 20 (50)
- Pumps and pipes: $25,000
- Chemical metering equipment: $10,000

Operating and Maintenance Costs
- Pond dredging: $20,000/yr
- Treatment chemicals
  - Lime: $22/kkg ($20/ton)
  - Flocculating agent: $2.2/kg ($1/lb)
- Energy unit cost: $0.01/kwh
- Maintenance: $10,000-11,000/yr

TABLE 43

WET PROCESS KAOLIN TREATMENT COSTS

PLANT SIZE 450,000 KKG PER YEAR OF Kaolin

PLANT AGE 30 YEARS PLANT LOCATION Georgia-South Carolina

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		447,000	463,000	487,000		
ANNUAL CAPITAL RECOVERY		49,200	51,800	55,600		
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		85,000	112,000	90,000		
ANNUAL ENERGY AND POWER		5,000	5,000	5,000		
TOTAL ANNUAL COSTS $		139,200	168,800	152,200		
COST/ KKG of Kaolin		0.31	0.38	0.34		
WASTE LOAD PARAMETERS mg/l	RAW WASTE LOAD					
TSS	10000	50	25	0		
Dissolved zinc	100	0.25	0.25	0		
pH		6-9	6-9	--		

All costs are cumulative.

LEVEL DESCRIPTION:

A — pond settling with lime treatment

B — A plus flocculating agents

C — pond settling and recycle to process (This should be satisfactory for cases where only cooling water and scrubber water are present. Process water will build up dissolved solids, requiring a purge.)

BALL CLAY

Those ball clay producers without wet air scrubbers do not have a discharge, and no costs are presented. The costs for producers using wet scrubbers are presented in Table 44. From the data presented in Section VII and from the observations of the project officer, the use of flocculants for the mine dewatering waste water may be necessary. These costs are also presented in Table 44.

The ball clay subcategory has a range of facility ages from 15 to 56 years. Age has not been found to be a significant factor on costs. Ball clay operations are located in the Kentucky-Tennessee rural areas and hence location is not a significant cost variance factor. The ball clay facilities range from 3,000 to 113,000 kkg/yr (3,300 to 125,000 ton/yr). The representative facility is 68,000 kkg/yr (75,000 ton/yr). Capital cost and operating cost variance factors for size are the same as for wet process kaolin.

Capital Costs Land cost, $/hectare ($/acre): 12,350 (5,000)
    Settling pond area, hectares (acres): 20 (50)
    Pumps and pipes: $25,000
    Chemical metering equipment: $10,000

Operating and Maintenance Costs Pond dredging: $20,000/yr
    Treatment chemicals
        Lime: $22/kkg ($20/ton) Flocculating agent: $2.2/kg ($1/lb)
    Maintenance: $10,000-11,000/yr

TABLE 44

BALL CLAY TREATMENT COSTS

PLANT SIZE 75,000 KKG PER YEAR OF Ball Clay

PLANT AGE 30 YEARS PLANT LOCATION Kentucky-Tennessee Region

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		89,000	92,000	97,000		
ANNUAL CAPITAL RECOVERY		9,800	10,300	11,100		
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		14,000	19,000	15,000		
ANNUAL ENERGY AND POWER		800	800	1,100		
TOTAL ANNUAL COSTS $		24,600	30,100	27,200		
COST/kkg of Ball Clay		0.33	0.40	0.36		
WASTE LOAD PARAMETERS (kg/kkg of ball clay)	RAW WASTE LOAD					
TSS		0.4-2.0	0.2	0		
pH		6-9	6-9	-		

LEVEL DESCRIPTION:

All costs are cumulative.

A — pond settling
B — A plus flocculating agent
C — closed cycle operation (satisfactory only for scrubbers and cooling water)

FELDSPAR

Feldspar may be produced as the sole product, as the main product with by-product sand and mica, or as a co-product of processes for producing mica. Co-product production processes will be discussed under mica. Dry processes (in western U.S.) where feldspar is the sole product have no effluent and no waste water treatment costs. Therefore, the only subcategory involving major treatment and cost is wet beneficiation of feldspar ore.

After initial scalpings with screens, hydrocyclones or other such devices to remove the large particle sizes, the smaller particle sizes are removed by (1) settling ponds or (2) mechanical thickeners, clarifiers and filters. Often the method selected depends on the amount and type of land available for treatment facilities. Where sufficient flat land is available ponds are usually preferred. Unfortunately, most of the industry is located in hill country and flat land is not available. Therefore, thickeners and filters are often used. The waste water pollutants are suspended solids and fluorides. There is also a solid waste disposal problem for ore components such as mud, clays and some types of sand, some of which have to be landfilled. Fluoride pollutants come from the hydrofluoric acid flotation reagent.

Treatment and cost options are developed in Table 45 for both suspended solids and fluoride reductions. Successive treatments for reducing suspended solids and fluorides are shown.

The reduction of fluoride ion level to less than 10 mg/l can be accomplished through segregation and separate treatment of fluoride-containing streams. This approach is already planned by at least one producer. A modest reduction of fluoride of less than 50 percent is presently achieved at only one facility with alum treatment that has been installed for the purpose of flocculating suspended solids.

The feldspar wet process subcategory consists of 6 facilities ranging in age from 3 to 26 years. Age is not a significant cost variance factor because of similar raw waste loads. The feldspar wet processing operations are located in southeastern and northeastern states in rural areas. Other than hilly terrain which has been accounted for, location has not been found to be a significant cost variance factor. The feldspar wet processing operations range in size from 45,700 to 154,000 kkg/yr (50,400-170,000 ton/yr). The representative facility is 90,900 kkg/yr (100,000 ton/yr). The range of capital costs

TABLE 45

WET PROCESS FELDSPAR TREATMENT COSTS

PLANT SIZE 90,900 KKG PER YEAR OF Feldspar

PLANT AGE 10 YEARS PLANT LOCATION Eastern U.S.

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		115,000	260,000	375,000	185,000	415,000
ANNUAL CAPITAL RECOVERY		18,700	42,100	60,800	30,100	70,800
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		107,500	132,500	157,500	118,500	156,500
ANNUAL ENERGY AND POWER		2,000	2,000	2,000	4,000	6,000
TOTAL ANNUAL COSTS $		128,200	176,600	220,300	152,600	233,300
COST/ KKG Feldspar		1.41	1.95	2.42	1.68	2.56
WASTE LOAD PARAMETERS (kg/ kkg of ore)	RAW WASTE LOAD					
Suspended Solids	260-530	0.6	0.3	0.3	0.3-3	0.1-0.3
Fluoride	0.22-0.25	0.2	0.1	0.03	0.2	0.03
pH	--	6-9	6-9	6-9	6-9	6-9

LEVEL DESCRIPTION:

All costs are cumulative.

A — settling pond for suspended solids removal, no fluoride treatment.

B — larger settling ponds plus internal recycle of some fluoride-containing water plus flocculation agents.

C — B plus segregation and separate lime treatment of fluoride water.

D — present treatment by thickeners and filters plus lime treatment for fluoride.

E — D plus segregation and separate lime treatment of fluoride water plus improved suspended solids treatment by clarifier installation.

for treatment is $36,800 to $250,000, and the range of annual operating costs is $18,400 to $165,000 as reported by the feldspar wet process producers.

Cost is estimated for capital directly proportional to the 0.9 power of size for treatments based on ponds and the 0.7th power for treatments based on thickeners. Operating costs other than taxes, insurance and capital recovery are approximately directly proportional to size.

Capital Costs
- Pond cost, $/hectare ($/acre): 30,600 (12,500)
- Settling pond area, hectares (acres): 0.4-0.8 (1-2)
- Thickeners, filters, clarifiers: 0-$50,000
- Solids handling equipment: $40,000-50,000
- Chemical metering equipment: 0-$50,000

Operating and Maintenance Costs
- Other solid waste disposal costs: 0-$0.5/ton
- Treatment chemicals: $10,000-25,000/yr
- Energy unit cost: $0.01/kwh
- Monitoring: 0-$15,000/yr

KYANITE

Kyanite is produced at three locations. Two of the three facilities have complete recycle of process water using settling ponds. A summary of treatment technology costs is given in Table 46. Approximately two-thirds of the cost comes from solid wastes removal from the settling pond and land disposal. Depending on solid waste load, costs could vary from approximately $1 to $4 per kkg of product.

The three facilities of this subcategory range in age between 10 and 30 years. There is no significant treatment cost variance due to this range. These facilities are in two southeastern states in rural locations; location is not a significant cost variance factor. The sizes range from 16,000 to 45,000 kkg/yr (18,000 to 50,000 ton/yr). The costs given are meant to be representative over this size range on a unit production basis, that is, costs are approximately directly proportional to size.

Capital Costs
- Pond cost, $/hectare ($/acre): 12,300 (5,000)
- Settling pond area, hectares (acres):10 (25)
- Pipes: $28,000
- Pumps: $4,400

Operating and Maintenance Costs
- Pond dredging and solids waste hauling: $82,500/yr
- Pond: $14,600/yr
- Pipes: $3,300/yr
- Energy unit cost: $0.01/kwh
- Pumps: $1,200/yr
- Labor: $3,000/yr
- Maintenance: $16,900/yr

TABLE 46

KYANITE TREATMENT COSTS

PLANT SIZE 45,000 KKG PER YEAR OF Kyanite

PLANT AGE 15 YEARS PLANT LOCATION Southeastern U.S.

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		80,000	157,400			
ANNUAL CAPITAL RECOVERY		9,700	19,100			
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		75,000	108,100			
ANNUAL ENERGY AND POWER		1,000	1,400			
TOTAL ANNUAL COSTS $		85,700	128,600			
COST/ KKG of Kyanite		1.90	2.83			
WASTE LOAD PARAMETERS (kg/ kkg	RAW WASTE LOAD					
Tailings	5500					
TSS		3	0			
pH		6-9	-			

LEVEL DESCRIPTION:

A — pond settling
B — A plus recycle

All costs are cumulative.

Note: Most of the above cost at A level (65-70%) is the cost of removal and disposal of solids from ponds.

MAGNESITE

There is only one known U.S. facility that produces magnesia from naturally occurring magnesite ore. This facility is located in a dry western climate and has no discharge to surface water by virtue of a combination evaporation-percolation pond. Capital costs for this treatment are $300,000 with operation/maintenance costs of $15,000/yr plus annual capital investment costs of $35,220.

SHALE AND COMMON CLAY

No water is used in either the mining or processing of shale and common clay. The only water involved is occasional mine drainage from rain or ground water. In most cases runoff does not pick up significant suspended solids. Any needed treatment costs would be expected to fall in the range of $0.01 to $0.05/kkg shale produced.

Shale and common clay facilities range from 8 to 80 years in age. This is not a significant variance factor for the costs to treat mine water since the eqiupment is similar. Facilities having significant mine water are located through the eastern half of the U.S. The volume of mine water is the only significant cost factor influenced by location. Facilities range from 700 to 250,000 kkg/yr (770 to 270,000 ton/yr). Size is not a cost variance factor, since the mine pumpout is unrelated to production rate.

APLITE

Aplite is produced at two facilities in the U.S. One facility with a dry process uses wet scrubbers. The waste water is ponded to remove suspended solids and then discharged. Waste water treatment costs were calculated to be $0.48/kkg product. The second processing facility uses a wet classification process and a significantly higher water usage per ton of product than the first facility. Except for a pond pumpout every one to two years, this facility is on complete recycle. The total treatment costs per kkg of product is $0.78. The estimated costs to bring the "dry process" facility to a condition of total recycle of its scrubber water are:

capital: $9,000
annual capital recovery:$1,470
annual operating and maintenance, excluding power and energy: $630
annual power and energy: $1,300
total annual cost:$3,400

Aplite is produced by two facilities which are 17 and 41 years old. Age has not been found to be a significant cost variance factor. Both aplite facilities are located in Virginia and, therefore, location is not a significant cost variance factor. The facilities are 54,400 kkg/yr (60,000 ton/yr) and 136,000 kkg/yr (150,000 ton/yr). The costs per unit production are applicable for only the facilities specified.

Capital Costs
    Pond cost, $/hectare ($/acre): 12,300-24,500
        (5,000-10,000)
    Settling pond area, hectares (acres): 5.5-32 (14-80)
    Recycle equipment: $9,000

Operating and Maintenance Costs
    Treatment chemical costs: $3,500/yr
    Energy unit cost: $0.01/kwh
    Recycle O & M cost: $1,900/yr
    Maintenance:$4,500-16,500/yr

Suspended solids are the major pollutant involved in the waste water from this category. In some wet processing operations pH control through addition of acid and alkalies is practiced. Neutralization of the final waste water may be needed to bring the pH into the 6-9 range. Mines and processing facilities may be either wet or dry. Dry operations have no treatment costs.

Mine Water

Rain water and ground water seepage often make it necessary to pumpout mine water. The only treatment normally needed for this water is settling ponds for suspended solids. Ponds are usually small, one acre or less. Costs for this treatment are in the range of $0.01 to $1.38/kkg talc produced. The large figure represents extremely small mines that would be mined in conjunction with other larger mines by a company.

Wet processes are conducted in both the eastern and western U.S. Waste water from Eastern wet processes comes from process operations and/or scrubber water. The usual method of treating the effluent is to adjust pH by the addition of lime, followed by pond settling. Treatment options, costs and resultant effluent quality are summarized in Table 47. Facilities not requiring lime treatment would have somewhat lower costs than those given. Wet process facilities in the Western U.S. are mostly located in arid regions and can achieve no discharge through evaporation. Costs for these evaporation pond systems were estimated to be the same cost as Level B. The required evaporation pond size in this case is similar to that needed for good settling pond performance.

Facilities in the talc minerals group range from 2 to 70 years of age. However, the heavy media separation and flotation subcategory consists of only three facilities of 10 to 30 years of age. This is not a significant treatment cost variance factor. The heavy media separation and flotation subcategory facilities are located in rural areas of the eastern U.S. This location spread is a minor cost variance factor. Talc minerals facilities range in size from 12,000 to 300,000 kkg/yr (13,000 to 330,000 ton/yr). The heavy media separation and flotation subcategory facilities range from 12,000 to 236,000 kkg/yr (13,000 to 260,000 ton/yr). The representative facility size selected is 45,000 kkg/yr (50,000 ton/yr). Over this range of sizes, capital costs can be estimated to be directly proportional to the exponent of 0.8 to size, and operating costs other

TABLE 47

WET PROCESS TALC MINERALS TREATMENT COSTS

PLANT SIZE 45,000 KKG PER YEAR OF talc minerals

PLANT AGE 25 YEARS PLANT LOCATION Eastern U.S.

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS: $						
TOTAL		100,000	150,000			
ANNUAL CAPITAL RECOVERY		11,700	17,600			
OPERATING AND MAINTENANCE COSTS: $						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		27,000	34,000			
ANNUAL ENERGY AND POWER		2,000	3,000			
TOTAL ANNUAL COSTS $		40,700	54,600			
COST/ kkg of products		0.89	1.09			
WASTE LOAD PARAMETERS (kg/ kkg of products)	RAW WASTE LOAD					
TSS	800 to 1800	0.3-1.3	0.3			
pH		6-9	6-9			

LEVEL DESCRIPTION:

A — lime treatment and pond settling
B — A plus additional pond settling

All costs are cumulative.

than capital recovery, taxes and insurance are approximately proportional to size.

Capital Costs
- Land cost, $/hectare ($/acre): 24,500 (10,000)
- Mine pumpout, settling pond area, hectares (acres): up to 0.4 (up to 1)
- Process settling pond area, hectares (acres): 2 (5)
- Pumps and pipes: $15,000
- Chemical treatment equipment: $35,000

Operating and Maintenance Costs
- Treatment chemicals
  - Lime: $22/kkg ($20/ton)
- Energy cost: $1,000-2,000/yr
- Maintenance: $5,000/yr
- Labor: $3,000-10,000/yr

GARNET

There are three garnet producers in the U.S., two in Idaho and one in New York State. Two basic types of processing are used: (1) wet washing and classifying of the ore, and (2) heavy media and froth flotation. Washing and classifying facilities have already incurred estimated waste water treatment costs of $0.16 per kkg of garnet produced. Heavy media and flotation process waste water treatment estimated costs already incurred are significantly higher, $5 to $10/kkg of product.

The quantity and quality of discharge at the Idaho facilities are not known by the manufacturer. Sampling was precluded by seasonal halting of operations. The hydraulic load per ton of product at the Idaho operations is believed to be higher than at the New York operation studied. The costs to reduce the amount of suspended solids in these discharges to that of the New York operation are estimated to be:

capital: $100,000
annual operating costs: $30,000

There are three garnet producers ranging in age from 40 to 50 years. Age has not been found to be a significant cost variance factor. Two of the garnet producers are located in Idaho and one in New York State. The regional deposits differ widely making different ore processes necessary. Due to this difference in processes, there is no representative facility in this subcategory. Treatment costs must be calculated on an individual basis. The garnet producers range in size from 5,100 kkg/yr to an estimated 86,200 kkg/yr (5,600-95,000 tons/yr). The differences in size are so great that there is no representative facility for this subcategory. Due to process and size differences, treatment costs must be calculated on an individual basis.

TRIPOLI

There are several tripoli producers in the United States. The production is dry both at the facilities and the mines. One small facility has installed a wet scrubber. There is only one facility in this subcategory that has any process waste water. This is only from a special process producing 10 percent of that facility's production. Therefore, there are no cost variances due to age, location or size.

DIATOMITE

Diatomite is mined and processed in the western U.S. Both mining and processing are practically dry operations. Evaporation ponds are used for waste disposal in all cases. The selected technology of partial recycle and chemical treatment is practiced at the better facilities. All facilities are currently employing settling and neutralization.

GRAPHITE

There is only one producer of natural graphite in the United States. For this mine and processing facility, mine drainage, settling pond seepage and process water are treated for suspended solids, iron removal and pH level. The pH level and iron precipitation are controlled by lime addition. The precipitated iron and other suspended solids are removed in the settling pond and the treated waste water discharged. Present treatment costs are approximately $20-25/kkg graphite produced.

JADE

The jade industry is very small and involves very little waste water. One facility that represents 55 percent of the total U.S. production has only 190 l/day (50 gpd) of waste water. Suspended solids are settled in a small tank followed by watering of the company lawn. Treatment costs are considered negligible.

NOVACULITE

There is only one novaculite producer in the United States. Processing is a dry operation resulting in no discharge. A dust scrubber is utilized and the water is recycled after passing through a settling tank. Both present treatment costs and proposed recycle costs are negligible.

NON-WATER QUALITY ENVIRONMENTAL ASPECTS, INCLUDING ENERGY REQUIREMENTS

The effects of these treatment and control technologies on air pollution, noise pollution, and radiation are usually small and not of any significance. Some impact on air quality occurs with sulfide wastes generated in sulfur production. However, the isolated locations of sulfur facilities and selection of treatment is usually sufficient to eliminate any problem. There is also radiation from phosphate ores and wastes. The concentration of radionuclides is low in materials involved with phosphate mining and beneficiating operations. Nevertheless, significant quantities of radionuclides may be stored or redistributed, because of the large volumes of slimes tailings and other solid wastes.

Large amounts of solid waste in the form of both solids and sludges are formed as a result of suspended solids removal from waste waters as well as chemical treatments for neutralization and precipitation. Easy-to-handle, relatively dry solids are usually left in settling ponds or dredged out periodically and dumped onto the land. Since mineral mining properties are usually large, space for such dumping is often available. For those waste materials considered to be non-hazardous where land disposal is the choice for disposal, practices similar to proper sanitary landfill technology may be followed. The principles set forth in the EPA's Land Disposal of Solid Wastes Guidelines (CFR Title 40, Chapter 1; Part 241) may be used as guidance for acceptable land disposal techniques.

For those waste materials considered to be hazardous, disposal will require special precautions. In order to ensure long-term protection of public health and the environment, special preparation and pretreatment may be required prior to disposal. If land disposal is to be practiced, these sites must not allow movement of pollutants such as fluoride and radium-226 to either ground or surface water. Sites should be selected that have natural soil and geological conditions to prevent such contamination or, if such conditions do not exist, artificial means (e.g., liners) must be provided to ensure long-term protection of the environment from hazardous materials. Where appropriate, the location of solid hazardous materials disposal sites should be permanently recorded in the appropriate office of the legal jurisdiction in which the site is located. In summary, the solid wastes and sludges from the mineral mining industry waste water treatments are very large in quantity. Since these industries generally have sufficient space and earth-moving capabilities, they manage it with greater ease than most other industries.

If the best practicable control technology regulations were promulgated for every subcategory, the added annual energy requirements would be approximately 555 million kw-hours. Much of this added energy requirement would be attributable to wet processing of crushed stone, phosphate rock and sulfur (on-shore salt dome).

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Effluent limitations which must be achieved by July 1, 1977, are based on the degree of effluent reduction attainable through the application of the best practicable control technology currently available. For the mineral mining industry, this level of technology was assessed based on the average of the best existing performance by facilities of various sizes, ages, and processes within each of the industry's subcategories. Best practicable control technology currently available emphasizes treatment facilities at the end of a manufacturing process, but also includes the control technology within the process itself when it is considered to be normal practice within an industry. Examples of waste management techniques which were considered normal practice within these industries are:

(a) select manufacturing process controls;
(b) recycle and alternative uses of water; and
(c) recovery and/or reuse of some waste water constituents.

Consideration was also given to:

(a) the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;
(b) the size and age of equipment and facilities involved;
(c) the process employed;
(d) the engineering aspects of the application of various types of control techniques;
(e) process changes; and
(f) non-water quality environmental impact (including energy requirements).

Process generated waste water is defined as any water which in the mineral processing operations such as crushing, washing and beneficiation, comes into direct contact with any raw material, intermediate product, by-product or product used in or resulting from the process. Storage pile and plant area runoff are not process generated waste water and are considered separately. All process generated waste water effluents are limited to the pH range of 6.0 to 9.0 unless otherwise specified.

Where sufficient data was available a statistical analysis of the data was performed to determine a monthly and a daily maximum. A detailed analysis of the daily TSS maximum and the monthly TSS maximum at a 99 percent level of confidence for phosphate slime ponds and kaolin ponds indicates that a TSS ratio of the maximum monthly average to the long term average of 2.0 is representative of settling pond treatment systems and of the daily maximum to the long term average of 4.0. It is judged that these ratios are also valid for the other parameters controlled in this category. This is an adequate ratio since the treatment systems for F, Zn and Fe for instance have controllable variables, such as pH and amount of lime addition. This is in contrast to a pond treating only TSS which has few if any operator controllable variables. This approach was not used for most subcategories of mine dewatering. Instead the data within each subcategory was individually assessed.

Non-contact cooling water is only occasionally used in this industry. No adverse environmental impact has been found for such discharges. No effluent limitation of non-contact cooling presently exists.

A mine is an area of land, surface or underground, actively used for or resulting from the extraction of a mineral from natural depostis. Mine drainage is any water drained, pumped or siphoned from a mine. Mine dewatering waste water is that portion of mine drainage that is pumped, drained or otherwise removed through the direct action of the mine operator. Pit pumpage of ground water, seepage and precipitation or surface runoff entering the active mine workings is an example of mine dewatering. The recommended pH of mine dewatering discharges is between 6.0 & 9.0. This pH range is not to supersede state water quality criteria for receiving waters with a pH outside of the 6.0 to 9.0 range. Discharges of non-process water such as mine water with a pH less than 6.0 may be discharged at a lower pH only if this pH is within the EPA approved state water quality criteria for pH for the receiving stream. This situation can arise in swamps.

Untreated overflow may be discharged from process waste water or mine dewatering impoundments without limitation if the impoundments are designed, constructed and operated to treat all process generated waste water or mine drainage and surface runoff into the impoundments resulting from a 10-year 24 hour precipitation event (as established by the National Climatic Center, National Oceanic and Atmospheric Administration for the locality in which such impoundments are located) to the limit specified as representing the best practicable control technology currently available. To preclude unfavorable water balance conditions resulting from precipitation and runoff in connection with tailing impoundments, diversion ditching should be constructed to prevent natural drainage or runoff from mingling with process waste water or mine dewatering waste water.

WASTE WATER GUIDELINES AND LIMITATIONS

DIMENSION STONE

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This is alternative C, ponding and recycle of process water. At least four facilities (3008, 3010, 3017, 3018) representing all the major types of stone presently achieve no discharge of process generated waste water.

Mine dewatering limitations which can be achieved are not more than 30 mg/l TSS. This quality of water is currently attained by dimension stone quarries as indicated by the data in Section VII. Furthermore, this quality of water is attained by crushed stone quarries which although nearly identical to dimension stone quarries are dirtier because of constant truck haulage. In any case where the water would exceed the limit, pit pumpout could be temporarily ceased until the water clears. Alternately flocculatants could be used on an intermittent basis or a settling pond could be inexpensively built. Poor quarry practice such as allowing muddy surface drainage to enter the quarry or frequent movement of equipment through flooded areas are the only expected causes of the limit being exceeded.

CRUSHED STONE (DRY)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated generated waste water pollutants because no process water is used.

CRUSHED STONE (WET)

The limitations set forth below are based on the use of the best practicable control technology currently available.

Discharge of process generated waste water pollutants from facilities that recycle waste water for use in processing, are not to exceed the following limitations.

Effluent Characteristic	Effluent Limitations

	Maximum for any one day	Average of daily values for thirty consecutive days is not to exceed
TSS	45 mg/l	25 mg/l
pH	Within the range of 6.0 to 9.0.	

Except as provided for in paragraph (1), there is to be no discharge of process generated waste water pollutants into navigable waters.

This technology represents alternatives C and, if necessary D. To implement this technology at facilities not already using the recommended control techniques would require the installation of pumps and associated recycle equipment and possible expansion of treatment pond facilities.

A survey was conducted by The National Limestone Institute of their participating members to determine, among other things, the number of crushed stone facilities that actually recycle all process generated waste water. Nineteen percent of the 104 wet processing plants surveyed reported that they presently meet the requirements of no discharge of process generated waste water and sixty-eight percent of the wet processors practice some recycle.

CRUSHED STONE (FLOTATION PROCESS)

The limitations set forth below are based on the best practicable control technology currently available.

Discharge of process generated waste water pollutants from facilities that recycle waste water for use in processing, is not to exceed the following limitations.

Effluent Characteristic	Effluent Limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days is not to exceed
TSS	45 mg/l	25 mg/l
pH	Within the range of 6.0 to 9.0.	

Except as provided for in paragraph (1), there is to be no discharge of process generated waste water pollutants into navigable waters. Facility 1975 is currently meeting this requirement. Facility 3069 is recycling about 70 percent of the process water to the washing mills. At facilities not totally recycling, flotation cell water can be recycled as wash water. Excess flotation cell water can be used as cooling water make-up and for dust control purposes which can consume large quantities of water.

CRUSHED STONE (MINE DEWATERING)

Mine dewatering limitations which can be achieved are:

Effluent Characteristic	Effluent Limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days is not to exceed
TSS	45 mg/l	25 mg/l
pH	Within the range of 6.0 to 9.0.	

This quality of water is currently attained by most crushed stone quarries as indicated by the data in Section VII. In cases where this limitation is exceeded, the causes can be attributed to the following: The settling area is often a small mined depression on the quarry floor referred to as a sump. It is almost never designed to efficiently remove suspended solids, and this could be too small for sufficient settling time. Most often the pump inlet is not placed in this sump to allow for maximum settling time. These deficiencies are usually compensated for by the excellent purity of the ground water and the inert nature of the hard rock versus clay material. Intrusion of muddy surface drainage into the quarry and constant equipment traffic in flooded areas are poor practices that will overload the sump. However, temporarily halting pit pumpout to allow the water to clear, use of flocculants on an intermittent basis, or construction of a settling pond will cure muddy quarry water problems.

CONSTRUCTION SAND AND GRAVEL (DRY)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process water is used.

CONSTRUCTION SAND AND GRAVEL (WET)

The limitations set forth below are based on the use of the best practicable control technology currently available.

Discharge of process generated waste water pollutants from facilities that recycle waste water for use in processing, is not to exceed the following limitations.

Effluent Characteristic	Effluent Limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days is not to exceed
TSS	45 mg/l	25 mg/l
pH	Within the range of 6.0 to 9.0.	

Except as provided for in paragraph (1), there is to be discharge of process generated waste water pollutants into navigable waters. This can be economically achieved by use of alternatives C, D or G which involve the ponding and/or recycle of all process waste water. More than half the subcategory is presently achieving no discharge.

This subcategory includes the dredging of non-navigable waters that are closed (wet pits), that is ponds entirely owned or leased from the pond owner. These frequently are flooded dry pits. Process water should be recycled from these pits. Overflow from these wet pits caused by rainfall and ground water infiltration is classified as mine dewatering. Runoff from areas outside the mine and plant should be excluded from the pit.

CONSTRUCTION SAND AND GRAVEL
(MINE DEWATERING)

Mine dewatering limitations which can be achieved are:

Effluent Characteristic	Effluent Limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days is not to exceed
TSS	45 mg/l	25 mg/l
pH	Within the range of 6.0 to 9.0.	

Except for emergency pumping after flooding, mine dewatering is unusual in this subcategory. Pits experiencing ground water flooding are usually allowed to fill and the deposit is dredged. This is in contrast to stone quarries where dredging is not possible for hard rock. In cases where it might be practiced, a sump arrangement like that for stone quarries would not be satisfactory and a well designed settling pond would be necessary. This is because sand deposits frequently contain clay. If good mining techniques are practiced a relatively constant raw waste load should result and pond upsets should not occur. The limitation if not then attained can be met by use of flocculants. This technology is being successfully practiced in many subcategories including sand and gravel process water, crushed stone and clays. In some cases mine water is treated in the process waste water pond system. This practice is allowed if the process facility uses recycled water.

CONSTRUCTION SAND AND GRAVEL (DREDGING WITH LAND PROCESSING)

This subcategory covers dredging in navigable waters. The limitations set forth below are based on the use of the best practicable control technology currently available for the discharge of process water not originating from the dredge pump.

Discharge of process generated waste water pollutants from facilities that recycle waste water for use in processing, are not to exceed the following limitations.

Effluent Characteristic	Effluent Limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days is not to exceed
TSS	45 mg/l	25 mg/l
pH	Within the range of 6.0 to 9.0.	

Except as provided for in paragraph (1), there is to be no discharge of process generated waste water pollutants into navigable waters.

This limit can be achieved by ponding and/or recycle of all non-dredge pumped process waste water. More than half this subcategory has achieved this level of technology for on-land treatment. No limits are recommended for dredge pumpage water pending further investigation of this subcategory. Discharges from dredges are covered under section 404 of the Act, "Permits for Dredged or Fill Material."

INDUSTRIAL SAND (DRY PROCESS)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology involves the recycle of air pollution control scrubber water after flocculation and settling. There is no water used in the processing of this mineral. This technology is employed by at least one facility (1107) in this subcategory.

INDUSTRIAL SAND (WET PROCESS)

The limitations set forth below are based on the use of the best practicable control technology currently available.

Discharge of process generated waste water pollutants from facilities that recycle waste water for use in processing, are not to exceed the following limitations.

Effluent Characteristic	Effluent Limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days is not to exceed
TSS	45 mg/l	25 mg/l
pH	Within the range of 6.0 to 9.0.	

Except as provided for in paragraph (1), there is to be no discharge of process generated waste water pollutants into navigable waters.

This technology (alternative B or C) involves settling of suspended solids by means of mechanical equipment and/or ponds and complete recycle of process water. Three (1019, 1989 and 3066) of the four facilities surveyed presently utilize the recommended technologies.

INDUSTRIAL SAND (ACID AND ALKALI FLOTATION PROCESS)

The limitations set forth below are based on the use of the best practicable control technology currently available.

Discharge of process generated waste water pollutants from facilities that recycle waste water for use in processing, is not to exceed the following limitations.

Effluent Effluent

Characteristic	Limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days is not to exceed
TSS	45 mg/l	25 mg/l
pH	Within the range of 6.0 to 9.0.	

Except as provided for in paragraph (1), there is to be no discharge of process generated waste water pollutants into navigable waters.

This technology (alternative B) involves the settling of suspended solids in ponds using flocculants where necessary, adjustment of pH where necessary and/or recycle of process water. Four (1101, 1103, 1019 and 1980) of the five facilities studied are currently meeting the recommended limitation by utilizing these technologies.

INDUSTRIAL SAND (HF FLOTATION PROCESS)

The limitations set forth below are based on the use of the best practicable control technology currently available.

Effluent Characteristic	Effluent Limitation kg/kkg (lb/1000 lb) of product	
	Monthly Average	Daily Maximum
TSS	0.023	0.046
fluoride	0.003	0.006

The above limitations were based on the average performance of the only facility (5980) in this subcategory. A maximum 914 l/kkg discharge flow was used as reported by the company. A TSS of 25 mg/l and F of 3.5 mg/l were used for the monthly average. This technology (alternative A) involves thickening, ponding to settle suspended solids, pH adjustment and partial recycle of process water.

INDUSTRIAL SAND (MINE DEWATERING)

Industrial sand mining is essentially identical to that for sand and gravel. Hence the same limitation is recommended.

Mine dewatering discharges are not to exceed the following limitations.

Effluent Characteristic	Effluent Limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days is not to exceed
TSS	45 mg/l	25 mg/l
pH	Within the range of 6.0 to 9.0.	

GYPSUM (DRY)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process water is used. The one facility using a wet air scrubber currently recycles this water.

GYPSUM (HEAVY MEDIA SEPARATION)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology involves the recovery of the heavy media, settling of suspended solids, and total recycle of process water. This technology is used at both facilities in this subcategory.

GYPSUM (MINE DEWATERING)

Mine dewatering discharge is not to exceed 30 mg/l TSS at any time. The data in Section VII shows that most mines can achieve this limitation. Little or no treatment is practiced. Gypsum mining is very similar to crushed stone mining.

ASPHALTIC MINERALS (BITUMINOUS LIMESTONE)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process waste water is used.

ASPHALTIC MINERALS (OIL IMPREGNATED DIATOMITE)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. The technology involves the recycle of scrubber water. There is no water used in the processing of this material. The one facility in this subcategory (5510) presently uses the recommended technology.

ASPHALTIC MINERALS (GILSONITE)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology (alternative B) involves ponding, settling and partial recycle of water. There is only one facility (5511) in this subcategory and it presently uses the recommended technologies.

ASBESTOS (DRY PROCESS)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants because no water is used in the process.

ASBESTOS (WET)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. The technology involves the total impoundment of all process waste waters. The techniques described are currently used by the only facility (1060) in this subcategory.

ASBESTOS (MINE DEWATERING)

Mine dewatering discharge is not to exceed 30 mg/l TSS. Only one facility is known to be dewatering at the present time, and the data in Section VII indicates that it can achieve the limitation. No problem is anticipated if other cases arise because of the hard rock nature of the deposit.

WOLLASTONITE

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process water is used. Mine dewatering is not to exceed 30 mg/l TSS at any time. There is no known mine dewatering, but because of the hard rock nature of the deposit, there should be no problem of achieving the limitation.

LIGHTWEIGHT AGGREGATE MINERALS (PERLITE)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process water is used. Mine dewatering is not to exceed30 mg/l TSS. Mine dewatering was not encountered, but it is not expected to present a problem since colloidal clays are not present.

LIGHTWEIGHT AGGREGATE MINERALS (PUMICE)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process water is used. Mine dewatering is not to exceed 30 mg/l TSS. Mine dewatering was not encountered, but it is not expected to present a problem since colloidal clays are not present.

LIGHTWEIGHT AGGREGATE MINERALS (VERMICULITE)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology (alternative A) involves ponding to settle suspended solids, clarification with flocculants if needed, and recycle of water to process. The two major facilities producing vermiculite (5506 and 5507) presently use the recommended technologies. Mine dewatering is not to exceed 30 mg/l TSS. Mine dewatering was not encountered, but it is not expected to present a problem,since colloidal clays are not present.

MICA AND SERICITE (DRY PROCESS)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process water is used.

MICA (WET GRINDING PROCESS)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology involves the settling of suspended solids and recycle of clarified water. One of the three facilities in this subcategory (2059) utilizes the recommended technologies. Another (2055) recycles part of the process waste water.

MICA (WET BENEFICIATION PROCESS, EITHER NON-CLAY OR GENERAL PURPOSE CLAY BY-PRODUCT)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology involves the settling of suspended solids in ponds and recycle of process water (alternative C or E). Four of the five facilities in this subcategory (2050, 2051, 2053 and 2058) are presently using the recommended technologies. The fifth (2054) was in the process of converting to total recycle at the time of the study.

MICA (WET BENEFICIATION PROCESS, CERAMIC GRADE CLAY BY-PRODUCT)

The limitation set forth below is based on the use of the best practicable control technology currently available.

	Effluent Limitation	
	kg/kkg of product (lb/1000 lb)	
Effluent Characteristic	Monthly Average	Daily Maximum
TSS	1.5	3.0

The above limitations are based on the performance of two facilities (2052 and 2057). The technology (alternative B or D) involves settling of suspended solids in ponds and lime treatment for pH adjustment prior to discharge.

MICA AND SERECITE (MINE DEWATERING)

Mine dewatering is not to exceed 30 mg/l TSS. One facility dewaters the mine into the process waste water pond in which flocculant is added. This water is planned to be completely recycled back to the plant (2054). Other mine dewatering is not known. In the event of mine dewatering, this water can be treated with flocculants on an intermittent basis to the above limitation.

BARITE (DRY PRODUCTION SUBCATEGORY

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process water is used.

BARITE (WET-LOG WASHING AND JIGGING AND FLOTATION)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process waste water pollutants. There is no discharge of process waste water pollutants during normal operating conditions. This technology (alternative B for washing and C for flotation) involves the containment of process waste water, settling of suspended solids, and recycle of process water during normal operating conditions. Where there is a discharge during periods of heavy rainfall, settling of suspended solids by ponding, flocculation, coagulation or other methods may be necessary. Tailings pond storm overflow is not to exceed 30 mg/l TSS. Four facilities in these subcategories in the same net precipitation geographical location are currently achieving this limitation.

BARITE (MINE DEWATERING)

Non-acidic mine dewatering is not to exceed 35 mg/l TSS. The following limits apply to acid mine dewatering:

Effluent Characteristic	Effluent Limitation mg/l Monthly Average	Effluent Limitation mg/l Daily Maximum
TSS	35	70
Total Fe	3.5	7.0

Mine dewatering is rarely practiced in barite mining. Where the mine water is non-acidic the limitation can be met by the intermittenent use of flocculants. There is one underground mine experiencing acid mine drainage.

FLUORSPAR (HMS)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology (alternative B) involves the impoundment of process water and total recycle. Five of the six facilities (2004, 2005, 2006, 2008 and 2009) studied are presently utilizing the recommended technologies (alternative B).

FLUORSPAR (FLOTATION)

The limitation set forth below are based on the use of the best practicable control technology currently available.

Effluent Characteristic	Effluent Limitation kg/kkg of product (lbs/1000 lb) Monthly Average	Daily Maximum
TSS	0.6	1.2
dissolved fluoride	0.2	0.4

The above limitations are based on the anticipated performance of treatment systems currently being installed at two facilities (facilities 2000 and 2001). They represent concentrations of approximately 50 mg/l for TSS and 20 mg/l for F. This technology (alternative B) involves the ponding in series and flocculation to reduce suspended solids and fluoride prior to discharge. An alternative technology is ponding and evaporation where possible. To implement this technology at facilities not already using the recommended control techniques would require the installation of ponds in series and flocculant addition facilities. Two facilities are presently installing the recommended technologies.

FLUORSPAR (DRYING AND PELLETIZING)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants because there is no process water.

MINE DEWATERING

Mine dewatering discharge is not to exceed 30 mg/l TSS as a daily maximum. This level is achieved by most mines as indicated by the data in Section VII. Settling ponds will be required by those operations that do not meet the limitations.

SALINES FROM BRINE LAKES (SEARLES LAKE)

The limitation which can be attained based on the best practicable control technology currently available is no net discharge of process waste water pollutants. These operations return the depleted brines and liquor to the brine source with no additional pollutants. The two facilities in this production subcategory are presently using the recommended control technologies.

SALINES FROM BRINE LAKES (GREAT SALT LAKE)

The limitation which can be attained based on the best practicable control technology currently available is no net discharge of process waste water pollutants. The only operation meets this requirement by the return of depleted brines and liquor to the lakes with no additional pollutants.

SALINES FROM BRINE LAKES (SILVER PEAK)

The limitation which can be attained based on the best practicable control technology currently available is no net discharge of process waste water pollutants. This involves the return of depleted brines and liquor to the brine source. The only facility in this production subcategory is presently using the recommended control technology, and there is no discharge to navigable waters.

BORAX

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process waste water pollutants. This technology (alternative A) involves the use of lined evaporation ponds. The only facility in this subcategory presently uses the recommended technology.

POTASH

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process waste water pollutants. This technology (alternative A) involves the use of evaporation ponds to contain process water. All facilities in this subcategory are presently using the recommended technology.

TRONA

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process waste water and mine dewatering pollutants. This technology (alternative B) involves the total impoundment and evaporation of all process waste water and mine water. All facilities either plan to or currently use this technology to dispose of waste water.

SODIUM SULFATE (BRINE WELL)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process waste water pollutants. This technology involves the total impoundment and evaporation of all process waste water. The two facilities representing this production subcategory are presently using the recommended control technologies.

ROCK SALT

The limitation set forth below is based on the use of the best practicable control technology currently available.

Effluent Characteristic	Effluent Limitation kg/kkg of product (lb/1000 lb) Monthly Average	Daily Maximum
TSS	0.02	0.04

The above limitation is based on the performance currently achieved by at least three facilities. Mine dewatering is included in the above limitation. This technology (alternative B or C) is the control of casual water with good water management practices and settling where required. To implement this technology at facilities not already using the recommended control techniques would require better water management practices and the installation of adequate settling facilities where required.

PHOSPHATE ROCK

The limitation set forth below is based on the use of the best practicable control technology currently available.

Effluent Characteristic	Effluent Limitation Monthly Average	Daily Maximum
TSS	30 mg/l	60 mg/l

The above limitation is based on the performance achieved at most of existing slime ponds as shown in Section VII. A statistical analysis was performed by fitting a three parameter log normal distribution to the data. Once the optimum value for Tau was found, the distribution was then extrapolated to determine the level of treatment presently achievable at a confidence level of 99 percent for the daily and average monthly values of TSS. It was judged that the average of all these values could not be used since the factors controlling the variability of effluent quality for the slime pond are beyond the practical control of the facility operator. These factors include wind, temperature, and aquatic growth, age of treatment facility and activity. This last point is demonstrated by the fact that volatile suspended solids comprised the majority of the TSS of the final effluents. Many plants experience high rates of algae growth in their settling ponds because of the nature of the intake water, or for other reasons such as the presence of nitrogen in the waste water (e.g. ammonia is used as a processing reagent). To prevent contamination of intake water, some facilities might have to switch sources of process water (from surface water to ground water). This change could cause additional environmental problems. The limitations reflect the degree of treatment achievable by properly constructed and maintained slime ponds. Some of the facilities not achieving the limits had insufficient data to be reliable (less than 12 data points). The two worst discharges were observed by the project officer to suffer considerable erosion of the earthen discharge ditch walls at points prior to the sample points. Other problems noted were incorrect sampling locations and procedures. At one facility the sample point included all untreated facility runoff in addition to the pond discharge. At another the sampler consistently stirred up sediment in the pipe bottom, and consequently the reported levels of TSS were incorrectly high. With proper operation all process ponds can achieve the standards 100 percent of the time.

If unpredictable pond or process upsets do occur, the present use of decant towers by the industry allows the facility operator to cease the discharge for a sufficient length of time in order that the suspended solids settle and be in compliance with the discharge limitations.

Fluoride and phosphorus are not regulated for the following reasons. First the existing treatments are operated to remove only suspended solids. The levels of fluoride appear to be related in part to the well water used in the flotation process. In addition the present fluoride concentrations are far below the practicable level of treatment used by related industries. It is expected that a significant portion of the phosphorus is in the form of a suspended solid and that removal of TSS will effect removal of phosphorus.

Although observed concentrations of radium 226 in effluents are generally below 3 pCi/l, the potential exists for effluent concentrations of this radionuclide to substantially increase. These increases are brought about primarily by higher suspended solid levels than allowed in the effluent or the introduction of acid to slime or effluents. All facilities sampled currently meet this radium 226 level. Therefore, this parameter will not be regulated at this time.

Most of the Florida, North Carolina and Tennessee facilities on which the guidelines were based are presently achieving the recommended limitations using these technologies. All

Western operations do or will shortly recycle all such waters.

SULFUR (FRASCH PROCESS, ANHYDRITE)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process waste water pollutants. Mine dewatering is included in the above limitations. This technology involves the chemical treatment and recycle of process water. Both facilities in this subcategory are using these technologies.

SULFUR (FRASCH PROCESS, SALT DOME OPERATIONS)

The limitations set forth below are based on the use of the best practicable control technology currently available.

Effluent Characteristic	Effluent Limitation mg/l Monthly Average	Effluent Limitation mg/l Daily Maximum
TSS	50	100
sulfide	1	2

The above limitations are based on the current performance (alternative C, D, E or F) of the 9 facilities in this subcategory. The quantity of water used in this subcategory is independent of the quantity of product. Therefore, effluent limitations based on quantity of pollutant per unit of production are not practical. Mine dewatering (bleed water) is included in the above limitations.

For facilities located in marshes that have insufficient land to build large enough oxidation ponds to achieve the above numbers the following limits apply.

Effluent Characteristic	Effluent Limitation mg/l Monthly Average	Effluent Limitation mg/l Daily Maximum
TSS	50	100
Sulfide	5	10

This technology involves oxidation of sulfides and the use of ponds to reduce suspended solids. If oxidation ditches are used by adding water to utilize its dissolved oxygen content, the TSS limits are to be applied on a net basis. Six of the nine facilities are presently using the recommended technologies. Well seal water is not regulated at this time.

SULFUR (FRASCH PROCESS - OFF-SHORE SALT DOME OPERATIONS)

No limits on off-shore operations are recommended at this time pending further investigation. Off-shore operations are defined as those open water operations sufficiently distant from land that the well bleed water wastes cannot be pumped ashore due to economic infeasiblity for aeration pond treatment.

MINERAL PIGMENTS (IRON OXIDES)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology involves the ponding and recycle of process waste water. This technology (alternative B) is presently being demonstrated by at least one major processor using process water. This facility (3022) uses a large pond common to the treatment of waste water from another larger production volume product and the discharge from the pond is attributable to the larger volume product. Two of the three facilities studied use no process water. This technology involves the ponding and recycle of process water when used. Mine dewatering is not to exceed 30 mg/l TSS based on the data from other subcategories.

LITHIUM MINERALS (SPODUMENE)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants (alternative A). There are only two spodumene facilities in operation. Facility 4009 currently operates on total recycle. There is some dam seepage and heavy storm overflow. Facility 4001 is constructing an impoundment to achieve total recycle.

Tailings dam seepage and tailings pond storm overflow are not to exceed 50 mg/l TSS. This is to be measured at the point of discharge. The process waste water limitations apply to the recovery of other minerals in the spodumene ore.

Mine dewatering is not to exceed 35 mg/l TSS. The mine water at the two mines appears to contain colloidal clay which will require periodic use of flocculants. Treatment to this level is successfully demonstrated by other subcategories including coal and fuller's earth.

BENTONITE

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants, because no process water is used. Mine dewatering is not to exceed 35 mg/l TSS. any time. No mine dewatering was found in this study. Where mine dewatering does occur the use of settling ponds or careful pumping of mine water to avoid turbulence is necessary. As noted in Section III, the difference between bentonite and fullers' earth is more of commercial use than geological significance. Thus the technologies used for fullers' earth are also applicable. The use of flocculants on an intermittent basis will be necessary if colloidal clays are present.

FIRE CLAY

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants since no process water is used. Mine dewatering for non-acidic waters is not to exceed 35 mg/l TSS. The data indicates that many mines can meet the limitation without treatment or additional treatment. In those cases where the limitation is exceeded the use of flocculants on an intermittent basis will be necessary. This technology has been successfully demonstrated in many other subcategories including fuller's earth. Acid mine drainage must meet the following limitations:

Effluent Characteristic	Monthly Average	Daily Maximum
TSS, mgl	35	70
Total Fe, mg/l	3.5	7.0

These limitations reflect the technology employed by the coal category. The limitations are directly applicable because fire clay is frequently associated with coal.

FULLER'S EARTH (ATTAPULGITE)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This condition is currently met by four facilities (3058, 3060, 3088 and 3089). This technology (alternative C) involves the use of dry air pollution control equipment and reuse of waste fines or recycle of fines slurry and scrubber water after settling and pH adjustment. Mine dewatering is not to exceed 35 mg/l. The data in Section VII indicates that this can be achieved by current practice.

FULLER'S EARTH (MONTMORILLONITE)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. Two facilities studied (3059,3073) presently use the recommended technology. Mine dewatering is not to exceed 35 mg/l TSS. The data in Section VII indicates that montmorillonite mines will have to occassionally use flocculation to meet the limitation (alternative C). Mine 3059 has successfully demonstrated flocculation and removal of TSS to very low levels for one of the highest concentrations of TSS in mine water that was allowed extensive time to settle. Successful use of flocculants at coal and other clay mines further demonstrate the technical feasibility.

KAOLIN (DRY PROCESSING)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This is feasible since no process water is used.

KAOLIN (WET PROCESSING)

The limitations set forth below are based on the use of the best practicable control technology currently available.

	Effluent Limitation	
Effluent Characteristic	Monthly Average	Daily Maximum
TSS, mg/l	45	90
Turbidity, JTU or FTU	50	100
Zinc, mg/l	0.25	0.50

The above limitations were based on a statistical analysis of the performance attainable by two facilities (3024 and 3025). In addition other Georgia kaolin producers have claimed that these limits are achievable. The technology involved (alternative B) is pH adjustment and flocculation. Some facilities flocculate first at a low pH and then pH adjust. Zinc precipitation by lime addition is necessary where zinc compounds are used to bleach the kaolin.

KAOLIN (MINE DEWATERING)

Mine dewatering from mines not pumping the ore as a slurry to the processing facility is not to exceed 35 mg/l TSS.

The data in Section VII indicates that this is currently being achieved.

The following limits apply to mine dewatering from mines pumping the ore as a slurry to the processing facility.

Effluent Characteristic	Effluent Limitation Monthly Average	Daily Maximum
TSS, mg/l	45	90
Turbidity, JTU or FTU	50	100

The use of clay dispersants in the slurry necessitates the use of flocculants and clarification in larger ponds than would be needed if the ore were transported by dry means.

BALL CLAY (WET PROCESSING)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology (alternative C) involves the use of dry bag collection techniques for dust control or, where wet scrubbers are employed, the use of settling ponds to reduce suspended solids and recycle.

BALL CLAY (DRY PROCESSING)

Where ball clay is processed without the use of wet scrubbers for air emissions control there is no need to discharge process waste water since it is either evaporated or goes to the product. Hence, the limitation which can be attained based on best practicable control technology currently available is no discharge of process generated waste water pollutants.

BALL CLAY (MINE DEWATERING)

Mine dewatering is not to exceed 35 mg/l TSS.. The data in Section VII indicates that the intermittent use of flocculants will be necessary to achieve the limitations. This technology is practiced in other subcategories.

FELDSPAR (FLOTATION)

The limitations set forth below are based on the use of the best practicable control technology currently available.

	Effluent Limitation kg/kkg (lb/1000 lb) of ore processed	
Effluent Characteristic	Monthly Average	Daily Maximum

TSS	0.60	1.2
Fluoride	0.175	0.35

The above limitations were based on the performance achieved by three exemplary facilities for TSS (3026, 3054 and 3067) and one of these three (3026) for fluoride reduction. This technology (alternative C) involves the recycle of part of the process waste water for washing purposes, then neutralization and settling the remaining waste water to reduce the suspended solids. In addition, fluoride reduction can be accomplished by chemical treatment of waste water from the flotation circuit and/or partial recycle of the fluoride containing portion of the flotation circuit. A concentration of 40 mg/l F can be achieved for this waste stream. This waste stream can then be combined with the remaining 75 percent of the non-HF contaminated water.

FELDSPAR (NON-FLOTATION)

The limitation which can be obtained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology is the natural evaporation of dust control water used in the process. This is the only water used in the process.

FELDSPAR (MINE DEWATERING)

Mine dewatering is not to exceed 30 mg/l TSS. Feldspar mining is a hard rock operation and the suspended solids appear to settle rapidly as in crushed stone operations. Mine runoff rather than dewatering is the normal method of water escape.

KYANITE

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology involves the recycle of process water from settling ponds. Facility 3015 is currently achieving the limitation. Facility 3028 operates on total recycle. However, excessive runoff results in periodic discharges. This can be rectified by exclusion of excess runoff from the process waste water pond. Mine dewatering is not to exceed 35 mg/l TSS. Mine dewatering was not practiced at the mines inspected.

MAGNESITE

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology involves either impoundment or recycle of process waste water. There is one facility in the U.S. and this facility currently uses the recommended technology.

SHALE AND COMMON CLAY

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants, since no water is used. Mine dewatering is not to exceed 35 mg/l TSS. This technology involves settling or the use of flocculants on an intermittent basis.

APLITE

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology involves the ponding of process waste water to settle solids and recycle of water. This technology is currently employed at facility 3016. Mine dewatering is not to exceed 35 mg/l TSS. Mine dewatering was not practiced at the mines inspected.

TALC, STEATITE, SOAPSTONE AND PYROPHYLLITE (DRY PROCESS)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process water is used.

TALC, STEATITE, SOAPSTONE AND PYROPHYLLITE (WASHING PROCESS)

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology involves the total impoundment or recycle of process waste water. All facilities in this subcategory currently employ the recommended control technology.

TALC, STEATITE, SOAPSTONE AND PYROPHYLLITE (HEAVY MEDIA AND FLOTATION)

The limitation set forth below is based on the use of the best practicable control technology currently available.

Effluent Characteristic	Effluent Limitation kg/kkg (lb/1000 lb) of product Monthly Average	 Daily Maximum
TSS	0.5	1.0

The above limitation is based on the performance achieved by three facilities (2032, 2033 and 2044) and a fourth facility (2031) achieving no discharge of process waste water. This technology (alternative A) involves pH adjustment of the flotation tailings, gravity settling and clarification. All facilities in this subcategory are presently using the recommended technologies.

TALC, STEATITE, SOAPSTONE, PYROPHYLLITE (MINE DEWATERING)

Mine dewatering is not to exceed 30 mg/l TSS. This limitation is based on the data from 8 mines given in Section VII.

GARNET

The limitations set forth below is based on the use of the best practicable control technology currently available.

Effluent Characteristic	Effluent Limitation Monthly Average	 Daily Maximum
TSS, mg/l	30	60

This technology involves pH adjustment, where necessary, and settling of suspended solids. The two facilities accounting for over 80 percent of the U.S. production are presently using the recommended technologies.

TRIPOLI

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. No process waste water is used in the dry processes. One operation uses a small quantity of water for dust collection. This water is treated with a flocculant and settled. This water should be of suitable quality to recycle. Alternately dry dust collection techniques can be employed.

Mine dewatering is not to exceed 30 mg/l TSS. Tripoli mine dewatering was not found in this study. Tripoli is not associated with colloidal clays; hence the limitations should be able to be achieved by settling.

DIATOMITE

The best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology involves the use of evaporation ponds and/or recycle of process water. Three facilities (5504, 5505 and 5500) of this subcategory representing approximately half the U.S. production utilize this recommended technology.

Mine dewatering is not to exceed 30 mg/l TSS. Mine dewatering was not found in this study. Diatomite is not associated with colloidal clays; hence the limitations should be able to be achieved by settling.

GRAPHITE

The limitations set forth below are based on the use of the best practicable control technology currently available.

	Effluent Limitation	
Effluent Characteristic	Monthly Average	Daily Maximum
TSS, mg/l	10	20
Total Iron, mg/l	1	2

The above average limitations were based on the performance achievable by the single facility in this subcategory. Both process waste water and mine dewatering are included. Concentration was used because of the variable flow of mine water. This technology involves neutralization of mine water and pond settling of both mine and process waste water.

JADE

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology involves the settling and evaporation of the small volume (less than 100 gallons per day) of waste water. The only major U.S. jade production facility presently employs these techniques. The mine is only infrequently operated, in fact only a few days in the last three years. Mine pumpout is therefore not regulated.

NOVACULITE

The limitation which can be attained based on the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology involves the total recycle of process scrubber water. There is only one facility in the U.S. It is presently using this technology. Mine dewatering is not practiced.

SECTION X

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Effluent limitations which must be achieved by July 1, 1983 are based on the degree of effluent reduction attainable through the application of the best available technology economically achievable. For the mining of minerals for the construction industry, this level of technology was based on the very best control and treatment technology employed by a specific point source within each of the industry's subcategories, or where it is readily transferable from one industry process to another. The following factors were taken into consideration in determining the best available technology economically achievable:

(1) the age of the equipment and facilities involved;
(2) the process employed;
(3) the engineering aspects of the application of various types of control techniques;
(4) process changes;
(5) the cost of achieving the effluent reduction resulting from application of BATEA; and
(6) non-water quality environmental impact (including energy requirements).

In contrast to the best practicable technology currently available, the best available technology economically achievable assesses the availability in all cases of in-process controls as well as control or additional treatment techniques employed at the end of a production process. In-process control options available which were considered include the following:

(1) alternative water uses
(2) water conservation
(3) waste stream segregation
(4) water reuse
(5) cascading water uses
(6) by-product recovery
(7) reuse of waste water constituents
(8) waste treatment
(9) good housekeeping
(10) preventive maintenance
(11) quality control (raw material, product, effluent)
(12) monitoring and alarm systems.

Those facility processes and control technologies which at the pilot facility, semi-works, or other level have demonstrated both technological performances and economic viability at a level sufficient to reasonably justify investing in such facilities were also considered in assessing the best available technology economically achievable. Although economic factors are considered in this development, the costs for this level of control are intended to be for the top of the line of current technology subject to limitations imposed by economic and engineering feasibility. However, this technology may necessitate some industrially sponsored development work prior to its application.

The attainable limitations for mine dewatering waste water discharges are the same as for the best practicable control technology currently available. The pH for all process generated and mine dewatering waste waters is to be between 6.0 and 9.0.

Untreated overflow may be discharged from process waste water or mine dewatering impoundments without limitation if the impoundments are designed, constructed and operated to treat all process generated waste water or mine drainage and surface runoff into the impoundments resulting from a 25-year 24 hour precipitation event (as established by the National Climatic Center, National Oceanic and Atmospheric Administration for the locality in which such impoundments are located) to the limitation specified as representing the best available technology economically achievable. To preclude unfavorable water balance conditions resulting from precipitation and runoff in connection with tailing impoundments, diversion ditching should be constructed to prevent natural drainage or runoff from mingling with process waste water or mine dewatering waste water.

The following industry subcategories were required to achieve no discharge of process generated waste water pollutants to navigable waters based on the application of the best practicable control technology currently available.

dimension stone
crushed stone (dry)
construction sand and gravel (dry)
industrial sand (dry)
gypsum
bituminous limestone
oil impregnated diatomite
gilsonite
asbestos
wollastonite

- perlite
- pumice
- vermiculite
- mica and sericite (dry)
- mica (wet, grinding)
- mica (wet beneficiation, either no clay or general purpose clay by-product)
- barite (dry)
- fluorspar (HMS)
- borax
- potash
- trona
- sodium sulfate
- sulfur (anhydrite)
- mineral pigments
- bentonite
- fire clay
- fuller's earth (montmorillonite and attapulgite)
- kaolin (general purpose grade)
- ball clay
- feldspar (non-flotation)
- kyanite
- magnesite
- shale and common clay
- aplite
- talc group (dry process)
- talc group (washing process)
- tripoli
- diatomite
- jade
- novaculite

The same limitations are recommended as the best available technology economically achievable.

The best available technology economically achievable is the same as the best practicable control technology currently available for the following subcategories, hence the same limitations are proposed:

- crushed stone (wet)
- crushed stone (flotation process)
- crushed stone (mine dewatering)
- construction sand and gravel (wet)
- construction sand and gravel (mine dewatering)
- construction sand gravel (dredging with land processing
- industrial sand (wet process)
- industrial sand (acid and alkali flotation process)
- Mica (wet beneficiation process, ceramic grade clay by-product)
- barite-wet (log washing, jigging and flotation)
- fluorspar (flotation)

salines from brine lakes
phosphate rock
lithium minerals (spodumene)
kaolin (wet processing)
garnet
graphite
mica (wet beneficiation process, ceramic grade clay by-product)
barite-wet (log washing, jigging and flotation)
fluorspar (flotation)
salines from brine lakes
phosphate rock
lithium minerals (spodumene)
kaolin (wet processing)
garnet
graphite

INDUSTRIAL SAND (HF FLOTATION)

The limitation which can be attained based on the best available technology economically achievable is no discharge of process generated waste water pollutants. This technology (alternative B) involves thickening, ponding to settle suspended solids, pH adjustment and total recycle of process water after segregation and total impoundment of the HF-containing segment of the process waste stream. This facility is located in an arid region and should be able to totally impound the HF-containing portion of its waste stream and recycle the remainder.

ROCK SALT

The limitations set forth below are based on the use of the best available technology economically achievable.

	Effluent Limitation kg/kkg of product (lbs/1000 lb)	
Effluent Characteristic	Monthly Average	Daily Maximum
TSS (Process and Mine Water)	0.002	0.004
Salt Storage Pile Runoff	No discharge	

The above limitations are based on the performance of at least one facility. This technology involves the use of drum filters, clarifiers or settling ponds to reduce suspended solids. Salt storage pile contaminated runoff can be eliminated by building storage silos and cones or by covering less frequently used piles with plastic or other fabric.

SULFUR (FRASCH PROCESS, SALT DOME OPERATIONS)

The limitations set forth below and based on the use of the best available technology economically achievable.

Effluent Characteristic	Effluent Limitation mg/l Monthly Average	Daily Maximum
TSS	30	60
sulfide	1	2

The above limitations are based on the current performance of 5 of the 9 facilities. The quantity of water used in this subcategory is independent of the quantity of product. Therefore, effluent limitations based on quantity of pollutant per unit of production are not practical. Mine dewatering both bleed water and seal water for this subcategory is included in the above limitations. The practiced technology is improved settling to reduce suspended solids and aeration to eliminate sulfides. If oxidation ditches are used by adding water to utilize its dissolved oxygen content, the TSS limits are to be applied on a net basis.

The best available technology for operations located in marshes that have limited land available to build large oxidation ponds to achieve the above limitations, the following limitations shall apply.

Effluent Characteristic	Effluent Limitation mg/l Monthly Average	Daily Maximum
TSS	30	60
sulfide	2	4

SULFUR (FRASCH PROCESS - OFF SHORE SALT DOME OPERATIONS)

No limitations are proposed at this time pending further investigation.

FELDSPAR (FLOTATION)

The limitations set forth below are based on the use of the best available technology economically achievable.

Effluent Characteristic	Effluent Limitation kg/kkg (lb/1000 lb) ore processed Monthly Average	Daily Maximum
TSS	0.6	1.2
Fluoride	0.13	0.26

The above limitation for fluoride is based on an improvement in exemplary facility performance by lime treatment to reduce fluorides to 30 mg/l in the HF contaminated segregated waste water. The limitation on suspended solids for best practicable control technology currently available is deemed also to represent the best available technology economically achievable. This technology (alternative C) involves the recycle of part of the process waste water for washing purposes, neutralization to pH 9 with lime to reduce soluble fluoride and settling to remove suspended solids. The selected technology of partial recycle is currently practiced at two facilities. Three facilities are currently using lime treatment to adjust pH and can readily adopt this technology to reduce soluble fluoride. All facilities are using settling equipment or ponds.

TALC MINERALS GROUP (HEAVY MEDIA AND FLOTATION)

The limitation set forth below is based on the use of the best available technology economically achievable.

Effluent Characteristic	Effluent Limitation kg/kkg (lb/1000 lb) of product Monthly Average	Daily Maximum
TSS	0.3	0.6

The above limitation was based on the performance of one facility (2032) plus one facility achieving no discharge of process water (2031). The best available technology economically achievable for the processing of talc minerals by the heavy media or flotation process is the same as the best practicable control technology currently available plus additional settling or in one case, conversion from wet scrubbing to a dry collection method to control air pollution. Two of the four facilities in this subcategory are presently achieving this level of effluent reduction using the recommended treatment technologies.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS AND PRETREATMENT STANDARDS

Limitations based on this level of technology are to be achieved by new sources. The term "new source" is defined in the Act to mean "any source, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance." This technology is evaluated by adding to the consideration underlying the identification of the best available technology economically achievable, a determination of what higher levels of pollution control are available through the use of improved production processes and/or treatment techniques. Thus, in addition to considering the best in-facility and end-of-process control technology, new source performance standards consider how the level of effluent may be reduced by changing the production process itself. Alternative processes, operating methods of other alternatives were considered. However, the end result of the analysis identifies effluent standards which reflect levels of control achievable through the use of improved production processes (as well as control technology), rather than prescribing a particular type of process or technology which must be employed.

The following factors were analyzed in assessing the best demonstrated control technology currently available for new sources:

a) the type of process employed and process changes;
b) operating methods;
c) batch as opposed to continuous operations;
d) use of alternative raw materials and mixes of raw materials;
e) use of dry rather than wet processes (including substitution of recoverable solvents from water); and
f) recovery of pollutants as by-products.

In addition to the effluent limitations covering discharges directly into waterways, the constituents of the effluent discharge from a facility within the industrial category which would interfere with, pass through, or otherwise be incompatible with a well designed and operated publicly owned activated sludge or trickling filter waste water treatment facility were identified. A determination was made of whether the introduction of such pollutants into the treatment facility should be completely prohibited.

Untreated overflow may be discharged from process waste water or mine dewatering impoundments without limitation if the impoundments are designed, constructed and operated to treat all process generated waste water or mine drainage and surface runoff into the impoundments resulting from a 25-year 24 hour precipitation event (as established by the National Climatic Center, National Oceanic and Atmospheric Administration for the locality in which such impoundments are located) to the limitation specified as the new source performance standard. To preclude unfavorable water balance conditions resulting from precipitation and runoff in connection with tailing impoundments, diversion ditching should be constructed to prevent natural drainage or runoff from mingling with process waste water or mine dewatering waste water.

The mine dewatering limitations are the same as for the best practicable control technology currently available. The pH limitation for all process generated and mine dewatering waste waters is to be between 6.0 and 9.0.

Based on the best practicable control technology currently available, attainable limits for the following industry subcategories were no discharge of process generated waste water pollutants to navigable waters.

dimension stone
crushed stone (dry)
crushed stone (flotation)
construction sand and gravel (dry)
construction sand and gravel (land processing)
industrial sand (dry)
industrial sand (acid and alkaline flotation)
gypsum
bituminous limestone
oil impregnated diatomite
gilsonite
asbestos
wollastonite
perlite
pumice
vermiculite
mica and sericite (dry)
mica (wet, grinding)
mica (wet beneficiation, either no clay or
  general purpose clay by-product)
barite (dry)
fluorspar (HMS)
borax
potash
trona

- sodium sulfate
- sulfur (anhydrite)
- mineral pigments
- bentonite
- fire clay
- fuller's earth (montmorillonite and attapulgite)
- kaolin (dry process)
- ball clay
- feldspar (non-flotation)
- kyanite
- magnesite
- shale and common clay
- aplite
- talc group (dry process)
- talc group (washing process)
- tripoli
- diatomite
- jade
- novaculite

The new source performance standard should be the same as the limitations based on the application of the best practicable control technology.

INDUSTRIAL SAND (HF flotation Process)

The industrial sand (HF flotation process) subcategory was required to achieve no discharge of process generated waste water pollutants to navigable waters based on best available technology economically achievable. The same limitations are recommended as the new source performance standard.

The new source performance standards for the subcategories listed below are to be the same as the limitations based on the best available technology economically achievable.

- crushed stone (wet)
- crushed stone (mine dewatering)
- construction sand and gravel (wet)
- construction sand and gravel (mine dewatering)
- construction sand and gravel (dredging with land processing)
- industrial sand (wet process)
- mica (wet beneficiation process, ceramic grade clay by-product)
- barite (wet and flotation)
- salines from brine lakes
- fluorspar (floatation)
- phosphate rock
- rock salt
- sulfur (Frasch process - salt dome)
- lithium minerals (spodumene)
- kaolin (wet process)
- feldspar (flotation)
- talc group (heavy media and flotation process)

garnet
graphite

SULFUR (FRASCH PROCESS-OFF SHORE SALT DOME OPERATIONS

No limitations are recommended at this time pending further investigation.

PRETREATMENT STANDARDS

tf Recommended pretreatment guidelines for discharge of process waste water into public treatment works conform in general with EPA Pretreatment Standards for Municipal Sewer Works as published in the July 19, 1973 Federal Register and "Title 40 - Protection of the Environment, Chapter 1 - Environmental Protection Agency, Subchapter D - Water Programs - Part 128 - Pretreatment Standards" a subsequent EPA publication. The following definitions conform to these publications:

The term "compatible pollutant" means biochemical oxygen demand, suspended solids, pH and fecal coliform bacteria, plus additional pollutants identified in the NPDES permit, if the publicly-owned treatment works was designed to treat such pollutants, and, in fact, does remove such pollutants to a substantial degree. The term "incompatible pollutant" means any pollutant which is not a compatible pollutant as defined above. A major contributing industry is an industrial user of the publicly owned treatment works that: has a flow of 50,000 gallons or more per average work day; has a flow greater than five percent of the flow carried by the municipal system receiving the waste; has in its waste, a toxic pollutant in toxic amounts as defined in standards issued under Section 307(a) of the Act; or is found by the permit issuance authority, in connection with the issuance of an NPDES permit to the publicly owned treatment works receiving the waste, to have significant impact, either singly or in combination with other contributing industries, on that treatment works or upon the quality of effluent from that treatment works.

No waste introduced into a publicly owned treatment works shall interfere with the operation or performance of the works. Specifically, the following wastes shall not be introduced into the publicly owned treatment works:

a. Wastes which create a fire or explosion hazard in the publicly owned treatment works;

b. Wastes which will cause corrosive structural damage to treatment works, but in no case wastes with a pH lower than 5.0, unless the works are designed to accommodate such wastes;

c. Solid or viscous wastes in amounts which would cause obstruction to the flow in sewers, or other interference with the proper operation of the publicly owned treatment works, and

d. Wastes at a flow rate and/or pollutant discharge rate which is excessive over relatively short time periods so that there is a treatment process upset and subsequent loss of treatment efficiency.

The following are recommended for Pretreatment Guidelines for a major contributing industry:

a. No pretreatment required for removal of compatible pollutants - biochemical oxygen demand, suspended solids (unless hazardous), pH, and fecal coliform bacteria;

b. Pollutants such as chemical oxygen demand, total organic carbon, phosphorus and phosphorus compounds, nitrogen and nitrogen compounds, and fats, oils, and greases, need not be removed provided the publicly owned treatment works was designed to treat such pollutants and will accept them. Otherwise levels should be at the best practicable control technology currently available recommendations for existing sources and the new source performance standards for new sources;

c. Limitation on dissolved solids is not recommended except in cases of water quality violations.

d. Incompatible pollutants shall meet the limitations representing the best practicable control technology currently available for existing sources and the new source performance standards for new sources.

SECTION XII

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Florida Phosphate Council
Georgia Association of Mineral Processing Industries
Gypsum Association
Indiana Limestone Institute
Louisiana Fish and Wildlife Commission
Louisiana Water Pollution Control Board
Marble Institute of America
National Clay Pipe Institute
National Crushed Stone Association
National Industrial Sand Association
National Limestone Institute
National Sand and Gravel Association
New York State Department of Environmental Conservation

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North Carolina Minerals Association
North Carolina Sand, Gravel and Crushed Stone Association
Portland Cement Association
Refractories Institute
Salt Institute
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SECTION XIII

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SECTION XIV

GLOSSARY

Aquifer - an underground stratum that yields water.

Baghouse - chamber in which exit gases are filtered through membranes (bags) which arrest solids.

Bench - a ledge, which in open pit mines and quarries forms a single level of operation above which mineral or waste materials are excavated from a contiguous bank or bench face.

Berm - a horizontal shelf built for the purpose of strengthening and increasing the stability of a slope or to catch or arrest slope slough material; berm is sometimes used as a synonum for bench.

Blunge - to mix thoroughly.

Cell, cleaner - secondary cells for the pretreatment of the concentrate from primary cells.

Cell, rougher - flotation cells in which the bulk of the gangue is removed from the ore.

Clarifier - a centrifuge, settling tank, or other device for separating suspended solid matter from a liquid.

Classifier, air - an appliance for approximately sizing crushed minerals or ores employing currents of air.

Classifier, rake - a mechanical classifier utilizing reciprocal rakes on an inclined plane to separate coarse from fine material contained in a water pulp.

Classifier, spiral - a classifier for separating fine-size solids from coarser solids in a wet pulp consisting of an interrupted-flight screw conveyor, operating in an inclined trough.

Collector - a heteropolar compound chosen for its ability to adsorb selectively in froth flotation and render the adsorbing surface relatively hydrophobic.

Conditioner - an apparatus in which the surfaces of the mineral species present in a pulp are treated with appropriate chemicals to influence their reaction during aeration.

Crusher, cone - a machine for reducing the size of materials by means of a truncated cone revolving on its vertical axis within an outer chamber, the annular space between the outer chamber and cone being tapered.

Crusher, gyratory - a primary crusher consisting of a vertical spindle, the foot of which is mounted in an eccentric bearing within a conical shell. The top carries a conical crushing head revolving eccentrically in a conical maw.

Crusher, jaw - a primary crusher designed to reduce the size of materials by impact or crushing between a fixed plate and an oscillating plate or between two oscillating plates, forming a tapered jaw.

Crusher, roll - a reduction crusher consisting of a heavy frame on which two rolls are mounted; the rolls are driven so that they rotate toward one another. Rock is fed in from above and nipped between the moving rolls, crushed, and discharged below.

Depressant - a chemical which causes substances to sink through a froth, in froth flotation.

Dispersant - a substance (as a polyphosphate) for promoting the formation and stabilization of a disperson of one substance in another.

Dragline - a type of excavating equipment which employs a rope-hung bucket to dig up and collect the material.

Dredge, bucket - a two-pontooned dredge from which are suspended buckets which excavate material at the bottom of the pond and deposit it in concentrating devices on the dredge decks.

Dredge, suction - a centrifugal pump mounted on a barge.

Drill, churn - a drilling rig utilizing a blunt-edged chisel bit suspended from a cable for putting down vertical holes in exploration and quarry blasting.

Drill, diamond - a drilling machine with a rotating, hollow, diamond-studded bit that cuts a circular channel around a core which when recovered provides a columnar sample of the rock penetrated.

Drill, rotary - various types of drill machines that rotate a rigid, tubular string of rods to which is attached a bit for cutting rock to produce boreholes.

Dryer, flash - an appliance in which the moist material is fed into a column of upward-flowing hot gases with moisture removal being virtually instantaneous.

Dryer, fluidized bed - a cool dryer which depends on a mass of particles being fluidized by passing a stream of hot air through it. As a result of the fluidization, intense turbulence is created in the mass resulting in a rapid drying action.

Dryer, rotary - a dryer in the shape of an inclined rotating tube used to dry loose material as it rolls through.

Electrostatic separator - a vessel fitted with positively and negatively charged conductors used for extracting dust from flue gas or for separating mineral dust from gangues.

Filter, vacuum - a filter in which the air beneath the filtering material is exhausted to hasten the process.

Flocculant - an agent that induces or promotes gathering of suspended particles into aggregations.

Flotation - the method of mineral separation in which a froth created in water by a variety of reagents floats some finely crushed minerals, whereas other minerals sink.

Frother - substances used in flotation to make air bubbles sufficiently permanent, principally by reducing surface tension.

Grizzly - a device for the coarse screening or scalping of bulk materials.

HMS - Heavy Media Separation

Hydraulic Mining - mining by washing sand and dirt away with water which leaves the desired mineral.

Hydrocyclone - a cyclone separator in which a spray of water is used.

Hydroclassifier - a machine which uses an upward current of water to remove fine particles from coarser material.

Humphrey spiral - a concentrating device which exploits differential densities of mixed sands by a combination of sluicing and centrifugal action. The ore pulp gravitates down through a stationary spiral trough with five turns. Heavy particles stay on the inside and the lightest ones climb to the outside.

Jigging - process used to separate coarse materials in the ore by means of differences in specific gravity in a water medium.

JTU - Jackson Turbidity Unit

Jumbo - a drill carriage on which several drills are mounted.

Kiln, rotary - a kiln in the form of a long cylinder, usually inclined, and slowly rotated about its axis; the kiln is fired by a burner set axially at its lower end.

Kiln, tunnel - a long tunnel-shaped furnace through which ware is generally moved on cars, passing progressively through zones in which the temperature is maintained for preheating, firing and cooling.

Launder - a chute or trough for conveying powdered ore, or for carrying water to or from the crushing apparatus.

Log washer - a slightly slanting trough in which revolves a thick shaft or log, carring blades obliquely set to the axis. Ore is fed in at the lower end, water at the upper. The blades slowly convey the lumps of ore upward against the current, while any adhering clay is gradually disintegrated and floated out the lower end.

Magnetic separator - a device used to separate magnetic from less magnetic or nonmagnetic materials.

mgd - million gallons per day

Mill, ball - a rotating horizontal cylinder in which non-metallic materials are ground using various types of grinding media such as quartz pebbles, porcelain balls, etc.

Mill, buhr - a stone disk mill, with an upper horizontal disk rotating above a fixed lower one.

Mill, chaser - a cylindrical steel tank lined with wooden rollers revolving 15-30 times a minute.

Mill, hammer - an impact mill consisting of a rotor, fitted with movable hammers, that is revolved rapidly in a vertical plane within a closely fitting steel casing.

Mill, pebble - horizontally mounted cylindrical mill, charged with flints or selected lumps of ore or rock.

Mill, rod - a mill for fine grinding, somewhat similar to a ball mill, but employing long steel rods instead of balls to effect the grinding.

Mill, roller - a fine grinding mill having vertical rollers running in a circular enclosure with a stone or iron base.

Neutralization - making neutral or inert, as by the addition of an alkali or an acid solution.

Outcrop - the part of a rock formation that appears at the surface of the ground or deposits that are so near to the surface as to be found easily by digging.

Overburden - material of any nature, consolidated or unconsolidated, that overlies a deposit of useful materials, ores, etc.

Permeability - capacity for transmitting a fluid.

Raise - an inclined opening driven upward from a level to connect with the level above or to explore the ground for a limited distance above one level.

Reserve - known ore bodies that may be worked at some future time.

Ripper - a tractor accessory used to loosen compacted soils and soft rocks for scraper loading.

Room and Pillar - a system of mining in which the distinguishing feature is the winning of 50 percent or more of the ore in the first working. The ore is mined in rooms separated by narrow ribs (pillars); the ore in the pillars is won by subsequent working in which the roof is caved in successive blocks.

Scraper - a tractor-driven surface vehicle the bottom of which is fitted with a cutting blade which when lowered is dragged through the soil.

Scrubber, dust - special apparatus used to remove dust from air by washing.

Scrubber, ore - device in which coarse and sticky ore is washed free of adherent material, or mildly disintegrated.

Shuttle-car - a vehicle which transports raw materials from loading machines in trackless areas of a mine to the main transportation system.

SIC - Standard Industrial Classification (code)

Sink-float - processes that separate particles of different sizes or composition on the basis of specific gravity.

Skip - a guided steel hoppit used in vertical or inclined shafts for hoisting mineral.

Slimes - extremely fine particles derived from ore, associated rock, clay or altered rock.

Sluice - to cause water to flow at high velocities for wastage, for purposes of excavation, ejecting debris, etc.

Slurry - pulp not thick enough to consolidate as a sludge but sufficiently dewatered to flow viscously.

Stacker - a conveyer adapted to piling or stacking bulk materials or objects.

Stope - an excavation from which ore has been excavated in a series of steps.

Stripping ratio - the ratio of the amount of spoil that must be removed to the amount of ore or mineral material.

Sump - any excavation in a mine for the collection of water for pumping.

Table, air - a vibrating, porous table using air currents to effect gravity concentration of sands.

Table, wet - a concentration process whereby a separation of minerals is effected by flowing a pulp across a riffled plane surface inclined slightly from the horizontal, differentially shaken in the direction of the long axis and washed with an even flow of water at right angles to the direction of motion.

TDS - Total Dissolved Solids

Thickener - an apparatus for reducing the proportion of water in a pulp.

TSS - Total Suspended Solids

Waste - the barren rock in a mine or the part of the ore deposit that is too low in grade to be of economic value at the time.

Weir - an obstruction placed across a stream for the purpose of channeling the water through a notch or an opening in the weir itself.

Wire saw - a saw consisting of one- and three-strand wire cables, running over pulleys as a belt. When fed by a slurry of sand and water and held against rock by tension, it cuts a narrow channel by abrasion.

TABLE 48

METRIC UNITS

CONVERSION TABLE

Multiply (English Units)		by	To obtain (Metric units)	
ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/ pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	F°	0.555 (°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	killowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	t	0.907	kkg	metric tons (1000 kilograms)
yard	y	0.9144	m	meters

*Actual conversion, not a multiplier

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